Ranching in the Floodplain of the Queguay River in Northwestern Uruguay: Sustainable Practices in the Face of Extreme Seasonal Variability and Woody Encroachment

By

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Abstract

Alianza del Pastizal is a non-profit conservation organization that works to promote conservation practices for sustainable cattle ranching in Uruguay, Paraguay, Argentina, and Brazil. In Uruguay, the ranchers in the Colonia Juan Gutierrez face challenges with water resource management during annual flood and drought seasonal events predicted to increase in magnitude with climate change. Additionally, the grasslands they use for livestock grazing are threatened by native and non-native vegetative species woody encroachment, possibly coming from expanding nearby forestry plantations. The purposes of this dissertation were to 1) investigate the perceptions of practices promoted by Alianza for woody encroachment and water resource management to most efficiently use available resources, and 2) to determine if woody encroachment and the forestry plantations are having effects on the vegetation types in the Juan Gutierrez properties and on the water dynamics of the sites analyzed: Colonia properties, conservation area, and the forestry plantations. For these purposes we used quantitative and qualitative methods including two Google Earth Engine tools, Global Forest Watch 2.0 and the Temporal Evapotranspiration Aggregation Method (TEAM), and syntheses of themes, surveys, and a Q-method based interview.

The findings indicate that prescribed burning for woody encroachment management is culturally unacceptable and highly regulated. However, there was positive receptivity to practices that align with a coexistence-based approach instead of an eradication approach. Carefully managed targeted grazing was identified as a possible option for woody encroachment management as it aligns with cultural, socioeconomic, and ecological contexts in the area. Ranchers assigned importance to caring for natural water bodies to use during future emergencies depending on their reliance on these water bodies for livestock watering sources.

Ranchers assigned low importance to this practice if they were already implementing it or if they were using natural water bodies as a complement to an artificial livestock watering system. Ranchers who had limited access to natural water bodies assigned high importance to the strategic placing of artificial livestock waterers in their property. Low importance was assigned to this practice if other infrastructure, like fencing, needed to be installed prior to an artificial watering distribution system, or if no additional artificial waterers were needed. The water use efficiency analysis indicated that vegetation types in the forestry plantations had periods of instability where biomass production and water processes were disrupted. The gross primary production analysis indicated potential effects that forestry plantations have on the vegetation types in the Colonia Juan Gutierrez properties. Vegetation types from all sites followed a similar GPP pattern but it was clear that the vegetation types from the properties followed the GPP values from the forestry plantations more closely than the GPP values from the conservation area. The role of Alianza in helping ranchers in the Colonia navigate these challenges involves their role as mediator between ranching communities and potential opportunities that may provide financial incentives or subsidies to implement conservation practices. Most importantly is Alianza's role in facilitating the dissemination of information and education to the Colonia ranchers regarding the proper implementation of these conservation practices.

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Chapter 1: Introduction

Photo by author. Sunset at the end of a field day.

This project started from a genuine curiosity to explore how ranching communities around the world manage their water resources within the sociopolitical contexts of their countries. My first experience with the topic was early in my doctoral studies when representatives from the Colombian organization CoLaborar came to visit Kansas. They connected with the extension office at Kansas State University (K-State) because they wanted to learn about drip irrigation for agricultural operations in areas suffering from high hunger rates and drought in the Guajira region of Colombia. I served as a translator and cultural advisor between my compatriots and the extension agents. During the days we spent together I learned about the different challenges that producers face when managing water resources during extreme seasonal events, and I also learned about the role that rural extension has in helping producers navigate these situations. I fell in love with the intersection between water, people, and the ranching tradition. Society and water resource relationships became the focus of my undergraduate research project and also the center of my masters thesis. Having this experience with CoLaborar and K-State extension opened a pathway for me to continue this line of research. Soon after this experience, the Center for Latin American and Caribbean Studies at the University of Kansas opened a funding opportunity for graduate students interested in carrying out research in a Latin American country that they had not visited before. Given the well-known ranching tradition of the Southern cone of South America, I searched for conservation organizations that emphasized ecological sustainability efforts in line with sociopolitical contexts. I came across the Alianza del Pastizal (hereafter Alianza) for the Southern Cone of South America. Alianza's regional coordinator welcomed my ideas and encouraged me to carry out a preliminary visit to one of the countries that the Alianza represents.

Alianza del Pastizal was founded in 2006 and became an alliance between ranching communities in Paraguay, Uruguay, Argentina, and Brazil. Ranchers who associate with the Alianza agree to work towards the preservation of the pampa biome and all its biodiversity by implementing conservation practices that the Alianza promotes. Alianza provides information, education, resources and a space for knowledge exchange among ranchers. The organizations representing the Alianza in each country are non-profit conservation organizations, funded in part by Bird Life International, and they focus on bird biodiversity as indicators for grassland ecosystem health. In Paraguay, Guyra Paraguay is the representative organization, in Uruguay it is Aves Uruguay, in Argentina it is Aves Argentinas, and in Brazil it is Save Brasil. Once a year, Alianza holds a cattle ranchers' meeting in one of the four allied countries. The first day of the meeting is dedicated to academic research presentations and closes with a barbeque where the signature Alianza del Pastizal beef is served prior to a cultural event with traditional Pampeana music. The following half-day is dedicated to a field visit to a ranch associated with the Alianza that showcases sustainable cattle ranching. Funding from the Center for Latin American and Caribbean studies from The University of Kansas allowed me to attend the ranching meetings held in Paraguay in 2017, Uruguay in 2018, and Brazil in 2019. I conducted preliminary research during the meeting in Paraguay, carried out the interviews for this dissertation during the meeting in Uruguay, and I followed up with participants during the meeting in Brazil.

While attending the cattle ranchers' meetings, I witnessed the comradery among ranchers from these different countries where the language barrier was nothing but a source of laughter. I saw ranchers sharing practical advice on problems that they could manage, but I also saw concerned ranchers who attend the yearly meetings in hopes of getting answers to more specific problems. Researchers who attempt to address these complex problems are met with a flurry of questions and commentary from ranchers. Since these yearly meetings are organized to benefit ranchers, presentations of this type often become an open discussion between researchers and the ranching community. During the Uruguayan meeting there were workshops organized where ranchers from all four allied countries came together to share and discuss topics proposed by the local conservation organizations Uruguayan Association of Grassland Ranchers (AUGAP), Aves Uruguay, and Plan Agropecuario de Uruguay. Although the format of these meetings is the same, the sociopolitical and environmental context of the country where the meeting takes place is reflected in what the local organization can offer and the focus topics of the presentations. The political, historical, and environmental context of each nation is equally as important as those contexts at the regional and global scale. To understand the state of the agricultural and ranching enterprise of a country we need to understand how external forces may or may have not shaped local decision-making processes leading to the current state of affairs.

Chapter 2 of this dissertation introduces the historical context in which the agricultural processes in Latin America became permeated by Western ideas. Ethnocentric ideas led decision makers in the USA to view communities in the developing South as backwards and in need of help. Modernization theory describes how standards of development based on the USA trajectory were imposed on Latin American societies, with the expectation they would reach similar development benchmarks. As expected, these efforts did not fulfill the goals that the USA had set for these countries and instead deeply affected traditional ways of practicing agriculture and cattle ranching. In Uruguay, the 2005 and 2006 governmental reforms to the Ranching, Agriculture, and Fishing Ministry (RAFMU) opened the door to younger generations who infused interdisciplinary ideas to the highly technical and scientific frameworks. These changes allowed for a more progressive and open rural extension service where experts and producers worked together in a horizontal collaboration instead of a top-down approach. This approach allows for more flexible management frameworks where cultural and traditional ways are welcome.

Uruguay's trajectory, however, can be considered as an exception to the rule as several Latin American countries continue to implement practices that rely on agrochemicals and heavy machinery. These methods often use an approach based on heavy control and eradication of processes that increase woody encroachment and the expansion of invasive species, for example woody encroachment on grassland landscapes. In Northwestern Uruguay, there is a ranching community in the Colonia Juan Gutiérrez which has actively embraced this progressive approach and actively collaborates with academic researchers, extension agents from local conservation organizations (AUGAP, Alianza del Pastizal, and Plan Agropecuario), and participates in national and internationally funded projects. Most of these efforts are geared towards gaining an understanding of the temperate pampa biome and ways in which it can be conserved through sustainable cattle ranching practices.

Ranchers from Colonia Juan Gutiérrez (Uruguay) participated in the initial implementation of the Toolkit for Ecosystem Service Site-based Assessment (TESSA) project, which was funded by international non-profits including BirdLife International. I learned about this project and this ranching community from the project coordinator, my collaborator and friend Daniela Schossler, a doctoral student at the University of the Republic of Uruguay. Daniela was to do fieldwork and sampling for the TESSA project in the properties of the Colonia Juan Gutiérrez a few weeks prior to the Uruguayan ranchers meeting. I shared with her my interest in interviewing ranchers in the Colonia and she proposed we combine resources and invited me to join her field sampling team. The team consisted of Daniela's advisor Dr. Carlos Nabinger; Fernando Cetrullo, president of the Sociedad de Fomento Rural de la Colonia Juan Gutiérrez (*Development Society of the Juan Gutiérrez Colony*); Horacio Silva Fagundez, an entomology graduate student from the University of the Republic of Uruguay; committee member Dr. Carol Baldwin from K-State; and Daniela and myself (photo 1 and photo 2).

I carried out some interviews while the rest of the team did field sampling. I also interviewed ranchers during the meeting, and the last interviews were done on the way from the township of Guichón to the township of Paysandú. This last portion of the interview series was coordinated by my longtime friend and cattle ranching consultant and coordinator at Guyra Paraguay, Lorena Sforza. My interview methods allowed me the flexibility to set up on short notice and in ad hoc settings (photo 3 and photo 4). I interviewed a total of 21 ranchers, with nine of the interviewees located within the Colonia Juan Gutiérrez. This dissertation is about them and for them. The remaining 12 interviews will be used in a larger study which will use the Q method[1] to explore the perceptions of ranchers regarding practices promoted by the Alianza del Pastizal to determine the likelihood of adoption and implementation of these practices.

Photo 1. Team photo after completing field sampling and interviews. From left to right on front row: Elba de los Santos Espiga, Walter Esteban Mesa Peña, Daniela Schossler, author. From left to right back row: Dr. Carlos Nabinger, Dr. Carol Baldwin, Horacio Silva Fagundez.

Photo 2. Team photo eating lunch at Fernando Cetrullo's ranch. From left to right: Dr. Carlos Nabinger, Daniela Schossler, Fernando Cetrullo, Horacio Silva Fagundez (with back to the camera). Photo by Dr. Carol Baldwin.

[1] For details on the applied use of the Q method refer to *Diana L. Restrepo-Osorio & J. Christopher Brown, 2018. "A Q methodology application on disaster perceptions for adaptation and resiliency in an Andean watershed symposium: water and climate in Latin America," Journal of Environmental Studies and Sciences, Springer; Association of Environmental Studies and Sciences, vol. 8(4), pages 452-468, December.*

Photo 3. Marianella Merello and author after being interviewed at the Alianza del Pastizal cattle ranchers meeting in Uruguay. On the table are the Q method materials used for the interview: the *Lona* (cloth tarp) and the 4”x6” cards with conservation practices written on them and placed on a semi-normal distribution by the participant.

Photo 4. Interview at Derbu Leonel Vidart Diaz’ ranch on the way from Guichol township to Paysandú township. On the floor are the cards with practices written on them placed in the semi-normal distribution by the participant. Author is recording the distribution of the cards in the demographic survey worksheet. Photo by Lorena Sforza.

The landscape traveling to our field and interview sites was mesmerizing with rolling hills, very much like the ones seen in Kansas, and cattle gathered around the trees in the distance (photo 5). The road often ran parallel to rivers and streams or ran above them with bridges or low water crossings (photo 6). Unfortunately, our view was often disrupted by large eucalyptus and pine plantations or large trucks transporting the harvest. This dissertation explores the dynamics among those elements: grasslands, savannas, bodies of water, cattle, forestry plantations, and the individuals who live in this area.

The most common topic throughout the interviews of the ranchers in the Colonia Juan Guiterrez were the challenges that seasonal flooding and drought events have on their ability to provide water for livestock. Given that the Colonia is located in the floodplains of the Queguay Grande and the Queguay Chico rivers, ranchers place high value on these water resources and actively care for them for long term use. This is especially true for some ranchers who utilize these natural water bodies as their main watering source for livestock. Other ranchers need complementary water sources, and if available, ranchers opt for other natural water bodies like ponds or streams, or artificial water sources like Australian tanks (chapter 3). Whatever the case may be, these ranchers have learned to care and coexist with the Queguay Grande and Queguay Chico rivers. Ranchers in the Colonia have built a strong adaptive capacity (chapter 3) to these seasonal water management challenges, however, they call for governmental subsidies or financial incentives (chapter 2) to increase or improve the water management systems they possess in order to face upcoming effects of climate change.

The magnitude of extreme seasonal events makes it increasingly difficult for ranchers to increase their adaptation and resilience to climate change, potentially jeopardizing the integrity of temperate grasslands in the Colonia. Based on previous studies, I explored the ways in which forestry plantations, or managed forests, impact the water cycle of the watershed including the increase of flooding after harvest and storm peaks (chapter 3). This is especially worrisome because these forestry plantations are located at the headwaters of the lower Queguay Grande river watershed, which can have significant effects on the watershed fluxes downstream (chapter 3). However, this is not the only issue associated with the forestry plantations, because these non-native species have the potential to encroach on the properties of the Colonia Juan Gutiérrez (chapter 4). While organizations like Alianza del Pastizal have included the topic of woody encroachment in their educational materials, it does not seem to receive the emphasis that it should. During our fieldwork sampling in different Colonia ranches, we observed several examples of woody encroachment. Witnessing this firsthand reinforced the importance of this phenomenon. Some observations included woody vegetation along the riparian areas of streams and a floodline made by woody debris that had traveled far into the property (pictures 8 and 9). The latter observation shook me as it demonstrated the challenges that ranchers have with seasonal floods and the various ways in which unintentional woody encroachment can occur (photo 7a).

Photo 5. Landscape of a property in the Colonia Juan Gutiérrez with pockets of trees in the background. Photo by Dr. Carol Baldwin.

Photo 6. Flooded historical low water crossing in the Guichón vicinity. Photo by Dr. Carol Baldwin.

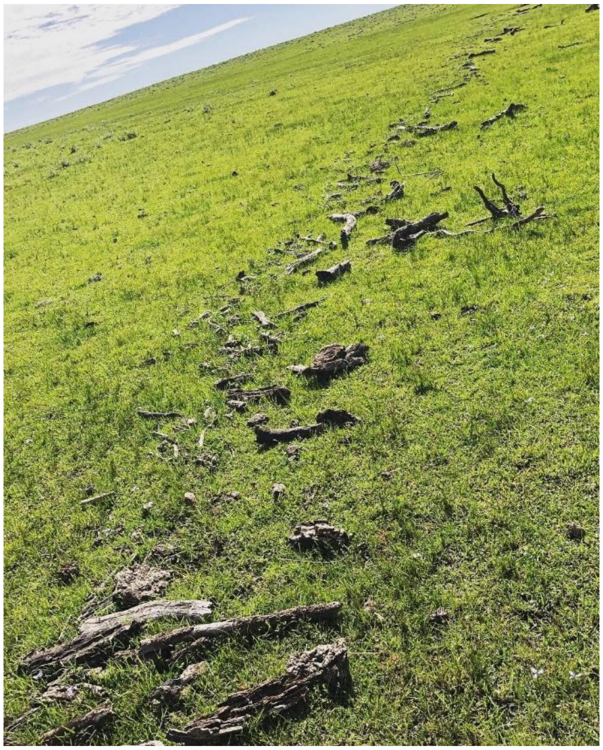

Photo 7a. Woody debris outlining the floodline within a property of the Colonia Juan Gutiérrez. Photo by Dr. Carol Baldwin.

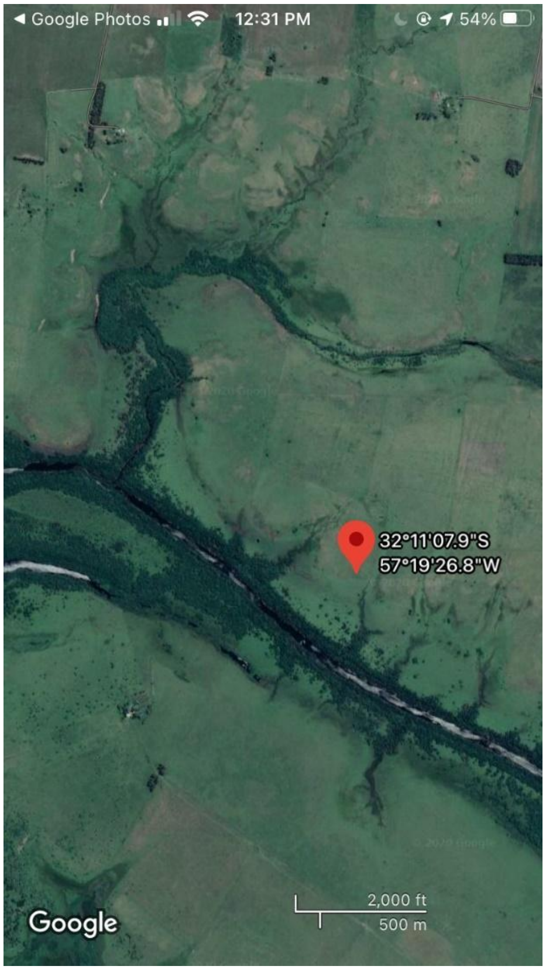

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Photo 8. Evidence of woody encroachment in a Colonia property. Photo by Dr. Carol Baldwin.

Photo 9: Evidence of woody encroachment in the riparian area of a stream in a Colonia property. Photo by Dr. Carol Baldwin.

I decided to carry out an investigation of potential effects that forestry plantations could already be having on the properties in the Colonia Juan Gutiérrez by using water use efficiency (WUE) values as a proxy for land cover change (chapter 4). Jim Coll, PhD Geography candidate at KU, developed a Google Earth Engine tool called TEAMS[2] (figure 1 below), which uses satellite imagery and land cover data from 2001-2018 to calculate values for different variables including WUE and its components, gross primary productivity (GPP) and evapotranspiration (ET). I collaborated with both Dr. Gabriel de Oliveira, former KU Geography PhD student and postdoc, and Jim Coll to calculate the WUE, GPP, and ET for the Colonia properties, the Rincon de Perez conservation area, and the forestry plantations. Fernando Cetrullo provided the shape file polygons for each property's paddock distribution and location in the Colonia, and Jim Coll imported them into the TEAMS tool making them available for this study. The satellite imagery and bounding boxes tool of the platform help in the exploration of areas that have no defined boundaries such as the conservation area and the forestry plantations. In summary, the exploratory analysis carried out in chapter 4 seeks to provide evidence of land cover change in the properties of the Colonia Juan Gutiérrez. This information provides a sense of urgency for local and national governmental, and nonprofit conservation organizations to address woody encroachment and promote management practices that align with the environmental, socio economic, and cultural contexts of ranchers in the Colonia.

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[2] https://jamesmcoll.users.earthengine.app/view/team

Coll, J. (2019). *Temporal Evapotranspiration Aggregation Method (TEAM)*. http://www.hydroshare.org/resource/7f43d1ff46d4403495427c59c0e1d790

The ultimate goal of this dissertation is to explore both the practices that are being encouraged by conservation groups to promote temperate grassland and biodiversity conservation, and the cultural traditions of the ranchers based on their Gaucho heritage. Understanding the perceptions of ranchers regarding management practices for woody encroachment and water resources is vital for organizations providing subsidies or financial incentives. This information helps them use available resources efficiently as it can be tailored to the variety of needs among ranchers. The Google Earth Engine analyses will provide evidence of the expansion of forestry plantations in the headwaters of the lower Queguay Grande river watershed and the potential effects that these plantations are having on woody encroachment of the Colonia properties. It is my hope that this information is used by ranchers, non-profit conservation organizations, and governmental organizations to confront impending climate change impacts on the ranching families of the Colonia Juan Gutiérrez.

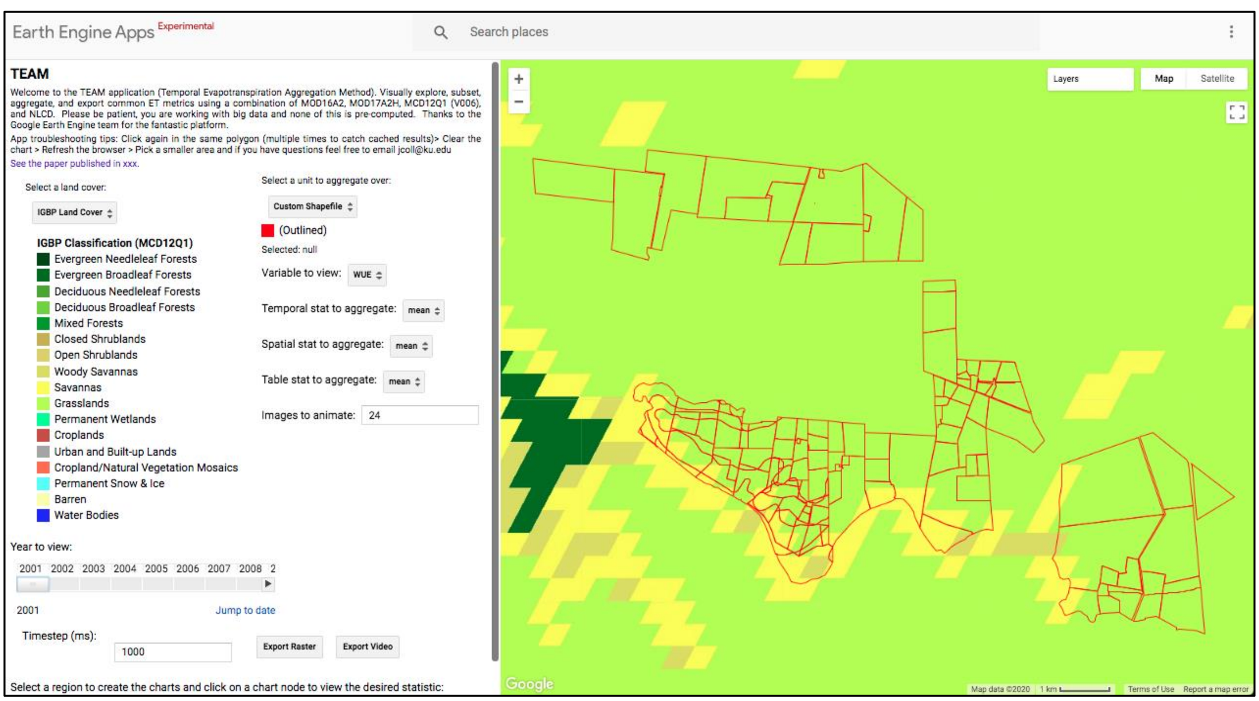

Figure 1. Screenshot of the Google Earth Engine TEAM tool showing the paddock distribution of the Colonia Juan Gutiérrez properties in a red outline

Chapter 2: Sustainable Cattle Ranching as a Woody Encroachment Management Tool in the Temperate Savannas of the Southern Cone of South America

Woody encroachment is a phenomenon in grasslands and savannas, and ranchers deal with it in various ways. This paper investigates ranchers' perceptions of woody encroachment and available management options in the Colonia Juan Gutiérrez in the temperate savannas of Northwestern Uruguay. On one hand there are practices derived from the Green Revolution era, such as herbicide development and use, which support an approach of woody vegetation eradication. This approach requires significant monetary investments and is typically harmful to water and soil health in different ways. On the other hand, so-called "cultural" practices support a management approach emphasizing coexistence with woody encroachment. This is a coexistence among livestock, woody vegetation, grasslands, and local biodiversity. This approach utilizes resources readily available to ranchers and supports adaptability, resilience, and sustainability in a heterogeneous ranching landscape. Coexisting with woody vegetation aligns with the ecological, socioeconomic, and cultural contexts, as well as the existing perceptions, preferences, and needs of ranching communities in areas of the world with limited resources for subsidies, monetary incentives, or locally funded research. Uruguayan Producers and extension agents working for local governmental organizations believe promote the management of woody vegetation encroachment under the coexistence approach uses techniques like targeted grazing, where different types of livestock are employed under a specific management regime to feed on specific vegetation types (Bailey et al., 2019). Although these management frameworks seem progressive and innovative and depart from the long-held influences of the green revolution, several ranchers in the Colonia Juan Gutiérrez have already been using them on their properties under the producers' own initiative. The role of extension agents, and organizations like the

Alianza del Pastizal and AUGAP (*Uruguayan Association of Grassland Ranchers*) has been critical in providing educational opportunities for ranchers. The emphasis of this education lies in the importance of adopting and implementing conservation practices that benefit biodiversity and production in ranches. While the ranchers interviewed subscribe to the goals of Alianza del Pastizal and AUGAP, not all have adopted the practices proposed by the Alianza, giving rise to the question of what influences the rejection or adoption of these practices. This question will be explored later in this chapter and in chapter 3.

The Green Revolution and the Export of Rural Extension (RE) Methods

In 1954, the USA instituted the Public Law 480 Program (PL-480), an initiative involving expansion of USA food exports and leading to the spread of the USA-led effort to industrialize agriculture. Although the PL-480 program was publicly presented as a famine relief effort, other clauses in this law led developing countries into food dependency on the USA. The other two clauses of this program allowed developing countries to purchase goods, initially wheat, at lower prices than it would cost to produce it in-country, or to exchange the goods for raw materials, most likely derived from natural resources (McMichael, 2017). By 1978, Latin American peasant communities suffered as wheat replaced traditional rice and corn. Once communities in developing nations changed to a wheat-based diet, it became easier for the USA to introduce other surplus agricultural goods. These goods focused on feed grains for livestock, and agricultural technology, which translated into petro-farming, a type of farming that uses heavy machinery and agrochemicals to increase production (Kremen et al., 2012; McMichael, 2017), and which had social and environmental impacts at multiple scales.

In developed countries, petro-farming resulted in practices such as feedlots and Concentrated Animal Feeding Operations, which can have a large impact on the environment due to the need to produce grain and manage animal waste. In countries such as Paraguay and Uruguay, small scale diversified agriculture, which has traditionally supplied local markets, has been converted to be part of the global trade system. Joining the global trade system with comparative advantages based on petro-farming was not beneficial to all actors involved; producers in developing countries found themselves depleting soil nutrients and overexploiting their natural resources. Funding institutions like USAID and the World Bank offered education and technology transfer in the form of rural extension (RE). These institutions also offered loans for producers attempting to salvage their establishments after falling into the chemical treadmill process; however, this option seemed like a long-term investment with dubious results. Counties choosing to take the loans also ended up needing to make structural adjustments demanded by lending institutions (McMichael, 2017). Producers often invested all their resources in high-yielding production of monocrops to participate in the global market. Subsistence farming plots had previously been converted to grasslands for cattle ranching or to the production of high yielding crops (Kremen et al., 2012).

Informal education through rural extension (RE) was an effective way to distribute information in rural communities in the USA, and by default was included in the reform processes headed by funding institutions. However, this method of disseminating information in Latin America, credited to Everett Rogers in 1962, was tailored for farming communities in the USA (Research et al., 1978); the introduction of an unmodified, culturally inappropriate RE heavily charged with ethnocentrism in countries outside the USA. was considered part of the process of agricultural modernization. Everett Rogers was a researcher in the field of communication and the diffusion of innovations who was influential in the development of extension programs.

Modernization and Rogers's Traditional RE

During the late 1960s and early 1970s, USA efforts to change peasant ways of life were framed in the modernization theory of the time, but sometimes resulted in communities in developing countries being stripped of their culture, belief systems, sovereignty, and self-governance. This type of modernization did not lead to "progress" as defined by the USA, but rather reinforced existing national and international power structures. This type of modernization is therefore regarded by many as a form of cultural and ideological colonization (Ibister, 2006; McMichael, 2017; Roberts & Hite, 2007; Blumberg & Cohn, 2016). Foreign RE approaches in developing nations have heavily impacted systems of local empirical knowledge. Unfortunately, agricultural practices derived from this RE approach became the gold standard for governments of developing countries, and as a result, traditional practices have often been disregarded.

The influence of modernization on a developing country's rural extension program is best explained by the two descriptors of this model: *productivism* and *diffusionism*. *Productivism* relates to Rogers's rural extension model that prioritized the most effective ways of producing high yields. Promoted by the USA land-grant university system, this model focuses on the aspects related to the production of commodities while disregarding the social factors of agricultural production (Landini, 2016; McMichael, 2017). The *diffusionist* dimension of this model assumes that the problems faced when implementing new technologies are to be confronted by the producer on their own (Landini, 2015). This is a top-down approach that aims to transfer information assuming that the producer's local knowledge is worthless. This in turn puts the producer in a subordinate position with limited possibilities to tailor farming improvement efforts to their needs (Landini, 2015). A hierarchy of power and knowledge emerges, hindering producer self-esteem, identity, and impairing their leadership, agency, and empowerment to propose new initiatives (Landini, 2015). It is therefore inappropriate to use rural extension methods based on the modernization framework with the expectation of achieving the USA ideal of development. Defining development may need to include specific connotations dependent on cultural traditions, historical contexts, and geography (Ibister, 2006).

Progressive and Traditional Rural Extension Coexistence

Transitioning from traditional top-down diffusionist RE to a more progressive RE service requires that both methodologies coexist fluidly to achieve project goals while satisfying the needs of the rancher and external funding agencies. According to Landini et al. (Landini, 2015; Landini & Riet, 2015), the concept of different, coexisting RE modes has attracted serious consideration (Landini, 2015; Vanclay, 2004). The structure of RE programs vary across countries due to historical governmental structures and policies. As we will see, countries like Uruguay emphasize a progressive approach to RE. Uruguay strives for a RE program that reinforces horizontal communication between producer and extension agents, instead of the traditional top-down, hierarchical extension service. Because RE serves as a bridge between sources of novel agricultural information and producers who need it, it is imperative that RE continue to be available and improved. A producer's participation in RE programs, independent of the use of progressive or traditional top-down diffusionist models, has a significant effect on the adoption of practices (FAO, 2017). However, a producer's participation in RE programs is influenced by how much RE agents have moved towards a more progressive, and inclusive, RE service (FAO, 2017).

Rural Extension in Latin America

In Latin America, a number of nations signed up for programs that promoted modernization with the goal of achieving USA standards of progress and development. Often this led to a devastating process that took years to recognize as faulty and rectify. Traditional RE became rooted and established within a decade in national and local organizations but was unable to withstand the 1980’s and 90’s structural adjustment demands coming from foreign financial lenders. In countries like Uruguay, for example, structural adjustments completely disassembled RE programs, and increased privatization (Landini, 2015; Landini & Riet, 2015). During the early 2000s poverty and hunger in Latin America again became an international concern, resulting in the revival of development initiatives for Latin America. Countries that had desired a shift in the RE framework in the past promptly intervened to counteract top-down approaches. These countries gathered different sectors of society, like academia and conservation organizations, to develop methods that prioritized the producers' needs and perceptions in culturally appropriate ways.

Uruguay could be regarded as one of the pioneers in this shift of RE due to its early initiatives to abolish the traditional top-down RE. In the 1970s, Uruguay wanted to replace traditional RE methodologies with alternate methods that highlighted more horizontal communication between extension agents and producers. In 2005 and 2006, the government of Uruguay encouraged the younger generation of extension agents to join the national RE restructuring program. Their participation infused Uruguayan RE with concepts from the social sciences in areas like participatory education, sociology, anthropology, and interpersonal communication. The aim was to promote producer participation in decision-making processes that would result in RE programs tailored to their needs. For the purpose of this study, this method will be referred to as progressive RE, which emphasizes a horizontal, not top-down, communication between RE agents and producers. The social science basis of this progressive method encourages the overturning of a development characterized by unequal power dynamics in search of a more meaningful and socially just development (Landini & Riet, 2015).

Progressive Rural Extension in the Southern Cone of South America

Uruguay's push for a progressive RE was more of an exception than the rule in the southern cone of South America, which is composed of Argentina, Chile, Brazil, Paraguay, and Uruguay. Brazil, for example, also adopted progressive ideas in the early 2000s when the USA efforts to eradicate hunger in Latin America were reactivated, and just like Uruguay, Brazil has continued supporting these ideas (Landini, 2016; Landini & Riet, 2015). The approach to RE of other countries, like Paraguay, reflects each country's political history and the priorities of their political class. The opportunity for reestablishing RE also made its way to Paraguay. Political favoritism, however, placed unqualified personnel into positions of power at RE organizations (Landini, 2015). Up to this day, corruption has prevented Paraguayan producers from benefiting from the resources designated for RE efforts. Independent organizations are providing their own RE services focused on their specific interests, and some are funded by international groups that may be interested in introducing progressive RE services. Nevertheless, the lack of enforcement on the ground, and lack of a RE agent education that includes social sciences, has resulted in a default mode of traditional top-down diffusionist RE ideas. Unlike in Uruguay and the USA, subsidies and financial incentives for producers are not a priority in Paraguay, where these funds are likely to be diverted to individuals in political offices (Landini, 2015). Therefore, producers are not incentivized to participate through provision of financial incentives and the ability to interact on a more nearly equal conversational basis with RE agents. Their adoption of innovative agricultural practices seems to come from a complex process involving interactions with RE agents alongside a personal decision to innovate.

Subsidies and Monetary Incentives in Uruguay

Historically, Uruguayan ranchers and agricultural producers relied on financial incentives that were distributed in a top-down fashion, passing through at least two governing levels before becoming available to the ranchers (Thompson, 2016). The bureaucratic process, including the lengthy time it took to obtain access to the funds and the small amount of funds actually received discouraged producers from adopting or adapting innovative agricultural practices. The situation changed with a decentralization movement, which began about 10 years ago (Thompson, 2016). Local organizations and farming communities were now encouraged to participate in the planning and decision-making processes through a progressive rural extension (RE) approach. Funds from the FAO became available to communities interested in four kinds of projects (Ministerio de ganadería, Agricultura y Pesca (*Ministry of Ranching, Agriculture, and Fishing*), MGAP, n.d.): 1) establishing or continuing small family ranching operations while building resilience to climate change (DGDR/MGAP, n.d.-a); 2) helping small family farm products enter the local and regional market through building strategic collaborations and alliances (DGDR/MGAP, n.d.-c); 3) supporting and guiding artisanal fishing families or small farming family producers wanting to sell their products at the national level (DGDR/MGAP, n.d.-d), and lastly, 4) the establishment of a pilot project to address poverty in rural areas (DGDR/MGAP, n.d.-b). The success of these programs, however, often depends on the competence of extension agents associated with MGAP and non-profit conservation organizations, in the implementation of these projects, including their dedication to helping the producer, their resourcefulness, and their expertise in technical support.

Traditional practices typically transmitted over time and even over generations (often called traditional ecological knowledge) (FAO, 2004) often take a back seat to the practices promoted by organizations making financial incentives available. Compared to USDA-funded development programs, FAO-funded Uruguayan RE incentive programs provide more flexibility in funded practices (USDA, n.d.) as subsidized support is still provided even when ranchers combine practices promoted by funding organizations with traditional practices. The producer has the option of deciding which practices to adopt according to their perceptions of what is best for a specific outcome (Alianza del Pastizal, 2017). On the other hand, incentive programs with stricter requirements such as grassland conservation practices funded by IDB may not allow the merging of the two. In this case, the producer must either take the risk of losing the incentive and implement the traditional practices (Sayre et al., 2012), or adopt a new practice, which can potentially result in financial benefits instead of fulfilling conservation goals.

The combination of subsidies or financial incentives and the horizontal relationships that the Uruguayan extension service provides are critical tools that can catalyze ranchers' adoption and implementation of conservation practices. Understanding the individual and collective perceptions of certain practices is a critical step in the planning processes when addressing particular problems in the ranching enterprise (Wilcox et al., 2018). Being aware of ranchers' perceptions regarding the proposed solutions for a problem allows for more efficient use of financial resources and a smoother transition to the adoption and implementation of particular practices. The individual relationships that the extension agents cultivate within ranching communities may be one of the most important elements in practice adoption. These relationships lead to a great deal of legitimacy and trust in the information and ideas that the extension agent proposes. Ranchers who are on the fence about adopting a practice may only need educational resources or evidence of a successful practice implementation by another rancher. The role of extension agents in addressing sensitive topics, like woody encroachment on grasslands, is key in communicating the possibilities when approaching this phenomenon.

Woody Encroachment

Woody encroachment is a phenomenon affecting grasslands and savannas worldwide and it is generally associated with negative effects on ranching, wildlife, and rangeland ecosystem services. Woody encroachment occurs when native or exotic tree or shrub species, accidentally or purposely, are introduced outside of their geographic areas (Archer et al., 2017; Culliney, 2005) or when there are changes in disturbance, such as grazing or fire regimes. Woody encroachment is facilitated by factors such as land degradation resulting from changes in land use, altered landscape management, fire frequency, and/or browsing or grazing regimes (Archer et al., 2017; DiTomaso et al., 2017). After woody vegetation has been introduced in an area, increasing atmospheric CO_2 and precipitation due to climate change can further enhance establishment (Archer et al., 2017). The increase of woody encroachment is best prevented by introducing disturbances early in the invasion process and at immature plant stages, because as woody vegetation is more pervasive and mature, it becomes more resilient and competitive (Archer et al., 2017).

Strategies to manage woody encroachment differ based on rancher priorities and perceptions of woody vegetation as either a resource or a nuisance (DiTomaso et al., 2017). In some parts of the world, producers understand that woody vegetation can provide additional ecosystem services and welcome the resultant increased vegetation heterogeneity and floral and faunal diversity (Archer et al., 2017) and their function as windbreaks. In some ecosystems, woody encroachment is believed to contribute to desertification and soil degradation (Wilcox et al., 2018); however, this is not always the case. In arid, semiarid areas or degraded systems woody species have sometimes been intentionally introduced to help in the recovery of water resources, decrease erosion, improve nutrient cycling and air and water quality, increase wildlife and pollinator habitat, provide medicinal and ornamental values, and in general to aid with the balance of ecosystem dynamics (Archer et al., 2017; Culliney, 2005; DiTomaso et al., 2017; Wilcox et al., 2018)

However, when woody vegetation has taken over a significant area of grasslands or savannas, a new ecological balance is created as the novel ecosystems alters vegetative structure and species composition, while the original ecosystem functioning is often lost (DiTomaso et al., 2017). Attempting to revert back to historic land cover patterns may be impossible or create opportunities for reinvasion or invasion of different species (DiTomaso et al., 2017). When this is the case, it may be more financially beneficial and more productive for ranchers to adapt to these novel, woody ecosystems rather than trying to reverse them (Archer et al., 2017; DiTomaso et al., 2017). If ranchers decide to integrate these woody vegetated areas into their management schema, priorities should lie in a proper cost-benefit analysis including evaluation of how these areas will be best utilized and managed to prevent further ecosystem degradation via encroachment (DiTomaso et al., 2017). Depending on the severity of woody encroachment, using these novel ecosystems as working landscapes in a ranch could facilitate long-term production under certain circumstances (Archer et al., 2017; Culliney, 2005; DiTomaso et al., 2017).

Targeted Grazing for Woody Encroachment Management

Options to control woody encroachment are fairly well known, but less known is how each option performs at the local level due to a scarcity of research. There are also limited financial resources for controlling woody encroachment and few incentives for adoption, leading to low adoption rates (Bailey et al., 2019; Culliney, 2005). International funding for research on woody encroachment tends to support conservation-focused projects without due consideration of rancher perceptions of the costs, benefits, or drawbacks of implementing certain management practices (Bailey et al., 2019). Additionally, external organizations tend to overlook potential ecological, social, and cultural contexts that may hamper conservation practice adoption and implementation (Bailey et al., 2019). Non-chemical control methods are often seen as being more culturally appropriate and are perceived as being more environmentally friendly (Bailey et al., 2019; Manning & Miller, 2011). Targeted grazing has advantages and disadvantages; however, carefully managed targeted grazing may provide a number of positive aspects. For example, it may help in the management of inaccessible areas; this practice leaves no herbicide residues; it may improve floral and faunal biodiversity; and it has the potential to convert rangeland and crop residue biomass into meat and fiber (Bailey et al., 2019). These less input-intensive practices typically use resources more readily available to ranchers or utilize biological tools that have minor impacts on the ecosystem level when implemented after thorough preliminary evaluation protocols (Culliney, 2005) but may not be adequate to achieve control.

Targeted grazing, also known as prescribed grazing or prescriptive grazing, uses different types of livestock to manage different types of vegetation under specific durations, intensity, and seasons depending on the rancher’s goals (Shapero et al., 2018). Ruminants have been divided into different categories based on their body size, mouth structure, and digestive categories

(Shapero et al., 2018). Cattle are grazers, feeding on roughage and used to manage grasses; goats are browsers used to manage shrubs and low hanging tree limbs; and sheep are intermediate feeders used to manage forbs, which are broadleaf herbs other than grass (Manning & Miller, 2011; Shapero et al., 2018). Targeted grazing can be combined with other woody encroachment management methods (Shapero et al., 2018). Coexistence of grazing with woody plant encroachment, which implies living with some level of herbage loss, depends on the extent to which woody species have replaced grasslands, the feasibility, cost, and acceptability of control options, and the nutritional and foraging needs of livestock.

Alternative Management Frameworks for Woody Encroachment

Methods used today to manage woody encroachment are based on often cost-prohibitive techniques such as use of heavy equipment and herbicides. These methods are employed to obtain a homogeneous landscape for maximum forage yield in the shortest amount of time, but like all control methods, they must continue to be applied to achieve woody plant control (Archer et al., 2017; Shapero et al., 2018). Management approaches that focus on investing significant resources in an attempt to recover historical land cover patterns using large scale restoration in developing countries have been identified as unsustainable and in opposition to the adaptation and resilience efforts that ranching communities may need to face climate change. Socio-economic considerations must be considered for successful implementation of innovative ways of managing woody vegetation encroachment (Archer et al., 2017; Shapero et al., 2018; Wilcox et al., 2018). The Integrated Brush Management System (IBMS), the Social-Ecological System (SES), the Coupled Human and Natural Systems (CHANS), the Integrated Pest Management (IPM), press-pulse woody plant encroachment (WPE) framework, and the concept of control versus eradication, all utilize a more comprehensive approach to woody encroachment as their framework is based on the socioeconomic, cultural, and ecological contexts of the area of interest.

The Integrated Brush Management System (IBMS) uses an understanding of the ecosystem services provided by woody vegetation, combined with knowledge of the biological responses of woody vegetation to climate, soils, topography, livestock, and wildlife, for long-term management planning and cost-benefit evaluations (Archer et al., 2017). IBMS suggests localized applications of woody encroachment methods over different times and spaces to increase native grassland species biodiversity (Archer et al., 2017). IBMS works under the understanding that perceptions of woody vegetation depend on cultural traditions, socioeconomic pressures, and on individual ranchers' land use priorities (Archer et al., 2017). For ranchers that prioritize land use management for both livestock and biodiversity, a proper balance of vegetative heterogeneity is vital (Archer et al., 2017). This management system acknowledges that short term management of woody vegetation is determined by socioeconomic pressures and land use priorities. Changes brought about by climate change, however, will prompt new priorities (chapter 3). Current woody encroachment management, therefore, needs to be developed with a long-term vision (Archer et al., 2017).

The Social-Ecological System (SES), also known as the Coupled Human and Natural System (CHANS), is based on the complex effects that socio-ecological interactions produce in ecosystems, highlighting the fact that these systems are needed for sustainable decision-making processes (Wilcox et al., 2018). The press-pulse WPE framework is interactive in nature and supports long-term interdisciplinary investigations of the interactions between the social and biophysical realms (Wilcox 2018). *Press variables* are those that can occur inconspicuously over longer periods of time, for example slowly changing average temperature and precipitation, or long-term impacts of human-directed grazing, whereas *pulse variables* are those that happen suddenly and sporadically, like droughts, fires, or floods (Wilcox et al., 2018). This and other frameworks highlight the fact that research is lagging in understanding land managers' perceptions of the ecosystem services that woody vegetation may provide in some circumstances, and that this is a major factor in determining the adoption or rejection of different management options (DiTomaso et al., 2017; Wilcox et al., 2018).

The Integrated Pest Management (IPM) approach, while including suppression, spread, and restoration strategies, also includes more holistic inquiries into socioeconomic dimensions, and it is based on sustainable and resilient approaches to woody encroachment management that consider the root of the problem (DiTomaso et al., 2017). Like IBMS, this management approach integrates a comprehensive understanding of the woody species of interest and encourages extension program evaluations that investigate ranchers' perceptions that may lead to the rejection or acceptance of woody encroachment management practices (DiTomaso et al., 2017). An IPM approach moves beyond restoration of historical land cover patterns to embrace a resilient system that provides greater ecosystem services and supports the wellbeing of ranching communities (DiTomaso et al., 2017).

STUDY AREA

The temperate savannas of northwestern Uruguay present pockets of woody species and trees which have traditionally coexisted successfully with the ranching tradition of the country (Ocaño et al., 2018). It is evident, however, that as is being seen elsewhere, woody encroachment is rapidly expanding (Ocaño et al., 2018; Pereira, 2020), elevating land management concerns. Herbicides, mechanical removal, livestock grazing, and prescribed burning are practices identified in the Ranching, Agriculture, and Fishing Ministry of Uruguay's (RAFMU) 2018 guide for managing native forests, *Manual de Manejo de Bosque Nativo en Uruguay.* for managing woody encroachment, but some of these practices appear to be incongruent with the ecological, social and cultural contexts and legal frameworks of ranching communities of Colonia Juan Gutiérrez.

Herbicide applications are culturally and regulatorily accepted, and substantial information is provided by RAFMU for the implementation of this practice. However, the potential for water pollution caused by herbicides, and the high cost associated with application often make ranchers hesitant to use this option (*personal communication with a producer, September 15, 2020*). Mechanical removal of well-established woody plants often requires a laborious removal process involving tagging, purchase or rental of appropriate machinery, and substantial fuel, time, and labor costs (Ocaño et al., 2018). Primary rancher objections to this control option include soil disturbance from uprooting the plant which can negatively affect other vegetative species of value to the producer, such as native grasses (*personal communication with a Uruguayan producer*). In summary, producers prefer not to use herbicide applications or mechanical removal methods for controlling woody plant encroachment due to cost, operational, and environmental concerns.

The use of prescribed burning in Uruguay is highly regulated, heavily discouraged, and culturally frowned upon. Memories of forest loss due to human-originated wildfires in forestry plantations and native forests have lingered, permeated, and influenced the decision-making processes of regulating authorities that issue prescribed burning permits (Ocaño et al., 2018). These historical events seemed to have focused on fire management of forests, leaving fire management of grasslands as an afterthought. RAFMU acknowledges that prescribed burning for the regeneration of palatable forage for livestock is the most common use of fire in the country

(Ocaño et al., 2018). However, the historic perceptions of prescribed burning seem to make it an option for some but not all ranchers. Additionally, there seems to be a generalized fear of the repercussions if a burn is not legally permitted (*personal observation*). Therefore, prescribed burning is restricted to those who have the means, time, and ability to go through the bureaucratic process of obtaining a permit and obtaining training, but it is not an easily accessible practice for the agricultural community as a whole. For this reason, producers tend to stay away from prescribed burning, and if they decide to use it, it is typically in sporadic, small, and closely controlled fires for the removal of vegetative debris while avoiding regulatory notice *(personal conversation with a producer)*.

RAFMU recommends Uruguayan producers log large invasive tree species, as it is likely that fire will not burn them completely due to lacking sufficient fuel. RAFMU recommends that the resulting debri be used in filling eroded areas in the field, or it should be left on the soil surrounding the base of the trees to decompose and contribute to the organic layer of the soil (Ocaño et al., 2018). RAFMU warns that fire can potentially increase invasive species colonization by creating favorable conditions for activating seed germination, further impacting native species (Ocaño et al., 2018). While fire use doesn't seem to be a priority for management of invasive species entering the native forests of Uruguay, prescribed burning could be an important practice in a grassland-woody plant coexistence strategy in the parkland (bosque parque) of the Uruguayan savanna, where an extensive ranching tradition is established (Ocaño et al., 2018).

The use of prescribed burning, herbicide, and mechanical options for managing woody invasives do not align with rancher ecological, social, legal, and cultural preferences and economic feasibility in northwestern Uruguay *(personal conversation with a producer),* leaving targeted grazing as a more attractive option from the perspective of the ranchers interviewed. Organizations such as Alianza have worked with ranching communities from Uruguay, Paraguay, Argentina, and Brazil since 2006 to provide science-based information, resources, and education among ranchers. Their role is to promote conservation and preservation of native grasslands through sustainable cattle ranching practices (Parera & Carriquiry, 2014) and to "conserve natural grasslands and their biodiversity in the Southern Cone of South America through coordinated actions between the four countries (Uruguay, Paraguay, Brazil, and Argentina), and between sectors of society (producers, civil organizations, academia, and governments), within the framework of harmonious and sustainable development of the region" (*Visión y Mision*, n.d.). The Alianza highlights the role of native grasslands as ecosystem service mitigators of climate change, floods, water quality, landscape, recreational and spiritual value" (*Visión y Mision*, n.d.), and in the preservation of ranching heritage and cultural traditions. The Alianza approaches sustainability at a multinational scale and includes multiple sectors of society in conservation, inviting both the agricultural and forestry sectors to properly use agrochemicals and conserve their native grasslands to benefit wildlife habitat, and water and soil health. The Alianza also directs its regional managers to maintain the native grasslands with conservation or protection status, and if available, to access governmental financial incentives for these efforts to continue funding the Alianza's conservation endeavors (*Visión y Mision*, n.d.).

The Alianza promotes practices that encourage livestock production on native grasses, while simultaneously providing wildlife habitat and preventing woody encroachment (Parera & Carriquiry, 2014). These practices include the building of paddocks using mobile electric fencing for grazing rotations, trimming unwanted vegetation with machinery, and temporarily deferring grazing to accumulate winter forage, as a seed bank, or as wildlife habitat. The Alianza recommends the same woody encroachment control practices as the RAFMU but additionally includes control options such as grazing and trampling, by goats and sheep, who browse more than cattle. This practice can be highly damaging to native ecosystems but could help in some already damaged but recovering areas. In this chapter we investigate what are the perceptions of the ranchers located in the Colonia Juan Gutierrez regarding the practices promoted by Alianza for woody encroachment management, in order to determine which practices are more likely to be adopted and implemented and therefore most efficiently use the available resources.

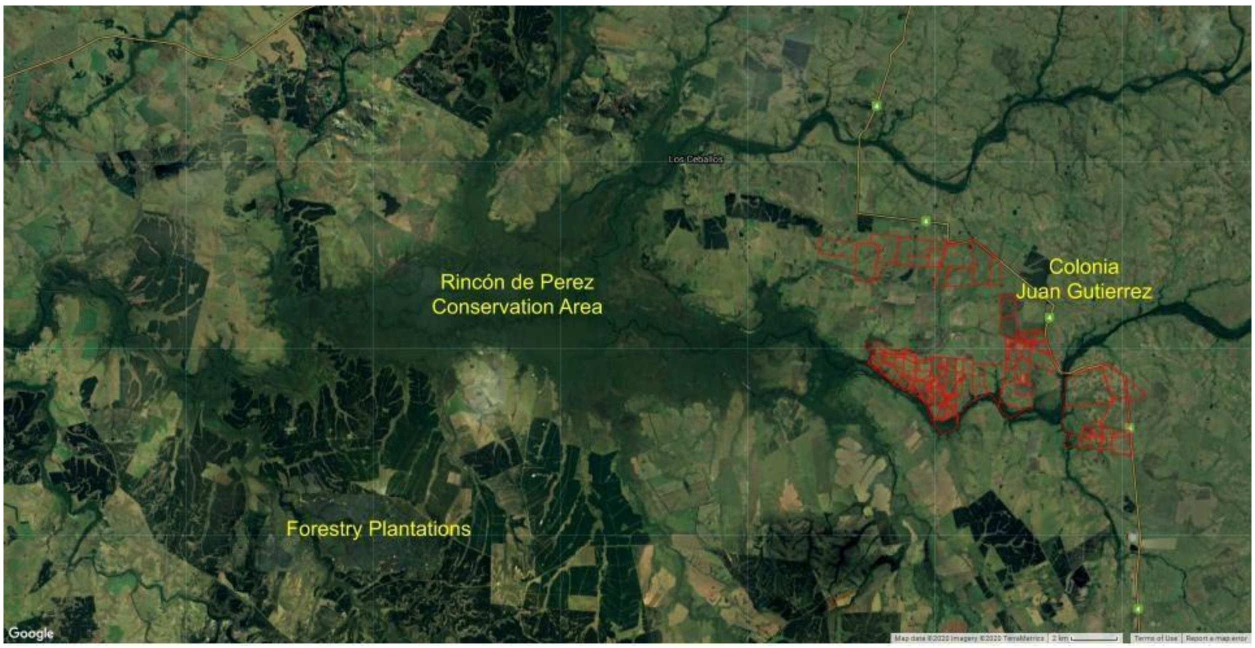

Figure 1. Location of the Colonia Juan Gutiérrez (red outlines), Rincon de Perez conservation area (medium shade of green), and Forestry plantations (darker shade of green)

METHODS

Temporal Evapotranspiration Aggregation Method (TEAM)[3]

Historical Aerial Imagery

The Google Earth Engine TEAM tool uses MOD16A2 and MOD17A2H satellite sensor-derived datasets (500 m pixel) to carry out its functions (Coll, 2019). We used TEAM to assess the land cover composition and distribution surrounding the Colonia Juan Gutiérrez in northwestern Uruguay. For this purpose, the shapefiles of the property boundaries and paddock distribution were requested and obtained from the president of the Sociedad de Fomento Rural de la Colonia Juan Gutiérrez (*Development Society of the Juan Gutiérrez Colony*). These shapefiles were then imported into the TEAM tool and made available as a *custom shapefile* under the *unit to aggregate over* function. No *land cover* was selected, and the *satellite* view was chosen in order to obtain the satellite imagery of interest. The frame was chosen to include the forestry plantations west of the Rincon de Perez conservation area and all the properties in the Colonia Juan Gutiérrez east of the conservation area. This frame remained fixed as the *years-to-view*-slider function showed one year at a time starting from 2001 to 2018. Each year's image was screenshot and the four images with the most representative forestry plot increase were chosen.

Land Cover Composition and Distribution

The shapefiles of the property boundaries and the paddock distributions within each property in the Colonia Juan Gutiérrez were obtained from the president of the Sociedad de

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[3] https://jamesmcoll.users.earthengine.app/view/team

Fomento Rural de la Colonia Juan Gutiérrez. TEAM tool developer Jim Coll imported these shapefiles into the TEAM tool platform and made them available as a *custom shapefile* under the *unit to aggregate* feature (Coll, 2019). The IGBP land cover classification MCD12Q1 database was selected in the *land cover* feature of the TEAM tool to obtain the land cover composition and distribution in the forestry plantations, the Rincon de Perez conservation area, and the properties in the Colonia Juan Gutiérrez.

The *Map Bounding Box (on click)* option was chosen as the *unit to aggregate over* and then water use efficiency (*WUE*) was chosen as the *variable to view* because this land cover analysis was part of a larger WUE project (chapter 4), the *mean* was the *temporal stat to aggregate*, the *mean* was also chosen as the *spatial stat to aggregate*, and the *mean* was also chosen as the *table stat to aggregate*. 2018 was the *year-to-view* for this analysis, the *images to animate* were left as the default of 24, and the *timestep (ms)* was also left as the default 1000.

The satellite viewing option was chosen initially to locate the area of interest. Once it was located, the area was enlarged using the zoom feature in the TEAM tool until the eastern and westernmost outlining borders of the area of choice were framed on the screen. The center of the area was visually estimated and selected with a click in order to activate the *map bounding box.* The WUE values for all vegetation types from 2001-2018 were displayed in a time series and monthly aggregate graphs, both of which were exported as a PNG and a CSV file to record the vegetation types at each zoom level. The first zoom level covers approximately $22km^2$. We framed the first zoom level *map bounding box* on the screen, which appears ghosted, and zoomed in again. Then we clicked the center of the area to create a new *map bounding box* on the second zoom level, which covers approximately $12km^2$. The same procedure was repeated for the third zoom level, which covers approximately $6km^2$. This procedure was done for the forestry plots, the conservation area, and properties in the Colonia Juan Gutiérrez.

The land cover composition and distribution analysis of the Colonia properties showed the presence of sporadic woody savanna pixels in the riparian savannas of the Queguay Grande river. One property in particular displayed an entire woody savanna pixel inside the southernmost paddock of the property. This pixel was labeled 3B and was further analyzed for land cover composition, in addition to land cover changes during the years 2007-2018.

IGBP Land Cover Descriptions:

- Grasslands: lands with herbaceous types of cover. Tree and shrub cover is less than 10%.
- Savannas: lands with herbaceous and other understory species, and with forest canopy cover between 10% and 30%. The forest cover height exceeds 2m.
- Woody savannas: lands with herbaceous and other understory species, and with forest canopy cover between 30% and 60%. The forest cover height exceeds 2m.
- Evergreen broadleaf forests: lands dominated by broadleaf woody vegetation with a percent cover >60% and height exceeding 2m. Almost all trees and shrubs remain green year-round. Canopy is never without green foliage.
- Deciduous broadleaf forest: lands dominated by woody vegetation with a percent cover >60% and height exceeding 2m. Consists of broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
- Mixed forest: lands dominated by trees with a percent cover >60% and height exceeding 2m. Consists of tree communities with interspersed mixtures of mosaics of the other four forest types. None of the forest types exceeds 60% of the landscape.

Rancher Survey and Interviews

The Colonia Juan Gutiérrez is composed of properties that are owned by the state and rented by families. The properties generally stay within a family until the rent is no longer affordable for the family, after which it returns to the state to be rented out again to another rancher. Generally, these properties remain within the same ranching families from generation to generation, each of which invests time, money, and effort in managing and improving the property, for example, the building of infrastructure, adopting and implementing conservation practices for water and soil health, and/or managing their properties to improve pastures. The ranches selected for this study were located on the floodplain of the Major Queguay River within Colonia Juan Gutiérrez and were managed by ranchers in agreement with the mission of the Alianza del Pastizal and the Asociación Uruguaya de Ganaderos del Pastizal, (AUGAP) (*Uruguayan Association of Grassland Cattle Ranchers*).

Rancher interviews were conducted to determine their receptivity towards the woody control practices promoted by the Alianza. It is important to note that although the participants in this study were all associated with the Alianza, they did not necessarily adopt or concur in the usefulness of any or all of the promoted practices. A rancher's association with the Alianza was based on an agreement to conserve the native grasses in their properties. This agreement was flexible to allow it to be tailored to the rancher's ecological, social, and cultural contexts and the legal frameworks in all four countries where the Alianza works. Despite all ranchers in this study being associated with the Alianza, there was significant variability in their perceptions of the promoted practices and their likelihood of being adopted

We interviewed some ranchers at their property and others during the XII Encuentro de Ganaderos de Pastizales Naturales del Cono sur de Sudamérica, Guichón, Uruguay, 2018 cattle ranchers meeting, an event organized by the Alianza and the AUGAP. Each year this ranchers meeting is hosted by one of the four countries (Argentina, Uruguay, Paraguay, and Brazil) where the Alianza del Pastizal is engaged to facilitate rancher and scientist networking and present the latest sustainable cattle ranching research in the region. Following presentations on the first day of the event, there was a barbeque social featuring local sustainably raised beef and a cultural show. The meeting closed the following day after a half-day field trip and barbeque at a ranch using sustainable cattle ranching practices promoted by the Alianza.

Survey and interview materials were reviewed and approved by University of Kansas institutional review board (IRB) prior to use[4]. Prior to being interviewed, interviewees provided their oral consent to participate in the study and have their responses recorded. Each rancher was assigned a code for privacy purposes and was asked to fill out a demographic survey detailing their gender, age, education, length of land tenure, grazing system, ranch acreage and how it compared in size to nearby ranches, the percent of the ranch covered by native grasses and forest, and the quantity of livestock by species.

Following the demographic survey, participants received five 4" x 6" cards, each with one of the following woody encroachment control practices inscribed on them: 1) use of prescribed burning, 2) creation of paddocks for rotational grazing, 3) temporary protection from grazing of selected areas for use as winter forage, native plant seed production, and/or wildlife habitat, 4) installation of mobile electric fencing, 5) mechanical removal of unwanted vegetation by using a lawnmower or similar equipment. Cards 2, 3, 4, and 5 were descriptions of practices promoted by the Alianza (promoted practices). Card 1 was used to explore the cultural context and legal framework for prescribed burning in Uruguay. Cards 2, 3, and 4 were practices related to targeted grazing. Rancher perspectives on the use of herbicides were ascertained through an open-ended question during the post-interview debriefing. Following card distribution, participants were asked to place the cards on a *lona* (cloth tarp) marked with a Likert scale ranging from -2 to +2 on it in whole integers. Only one card could be placed on each of the

[4] Record ID numbers: 23032287; 10218798; 23032288

definitely not (-2) and definitely yes (+2) options, to make priorities clear. Participants were then asked to place the remaining three cards on the Lona Likert scale with the following statement in mind: *I would be willing to adopt the following practices if there were no funding limitations.* To close, participants were asked to share their reasoning for placing the cards where they did on the Likert scale.

The Q method uses both quantitative and qualitative approaches to explore human subjectivity about a topic (Restrepo-Osorio & Brown, 2018). The Q set administration process provides an intimate space for participants to reflect on their views and ideas while sorting the cards on the semi-normal distribution. The post-sort interview provides participants with an opportunity to articulate the reasons for the resulting sorting distribution. This is viewed as one last possibility for participants to change the card sorting and define how they want their perception to be represented in the Q sort pattern. Ultimately, the Q method helps participants to situate themselves in a perception group and to recognize the variation of perceptions among stakeholders (Restrepo-Osorio, 2015; Restrepo-Osorio & Brown, 2018).

Synthesis of Themes

Audio recordings were transcribed in Spanish by a third party. Translation to English was not requested in order to preserve cultural meanings, sayings, and other subjective information embedded in the original interview language. Transcribed responses for each individual practice were collated together for analysis. Transcripts were also parsed into quotes and analyzed, then grouped into themes. Quotes that revealed key concepts and viewpoints were translated to English by the author (Saldaña, 2009).

RESULTS

Temporal Evapotranspiration Aggregation Method (TEAM) Tool

Historical Aerial Imagery

The TEAM tool was used to assess the state of the Colonia Juan Gutiérrez and its surroundings. We initially noted the extent of the conservation area Ricon de Perez, which is the largest forested area in the country (Guido & Lopez Marsico, 2010). At the same time, the extent of the forestry plantations was evident as they seemed to closely outline the eastern portion of the conservation area. Satellite imagery was used to investigate the historical trends associated with the forestry plantations. It was evident that the forestry plantations were rapidly growing and expanding westward, towards our properties of interest in the Colonia Juan Gutiérrez (Figure 2). The expansion and proximity of these plantations, which are typically composed of exotic eucalyptus and pine for paper production, could be initiation points for woody encroachment into the Colonia properties (Chescheir et al., 2008; Fonseca et al., 2013; Ocaño et al., 2018; *Visión y Mision*, n.d.). To further investigate, we obtained the land cover composition of these three main areas: the forestry plantations, the Rincon de Perez conservation area, and the Colonia Juan Gutiérrez ranches included in the interviews.

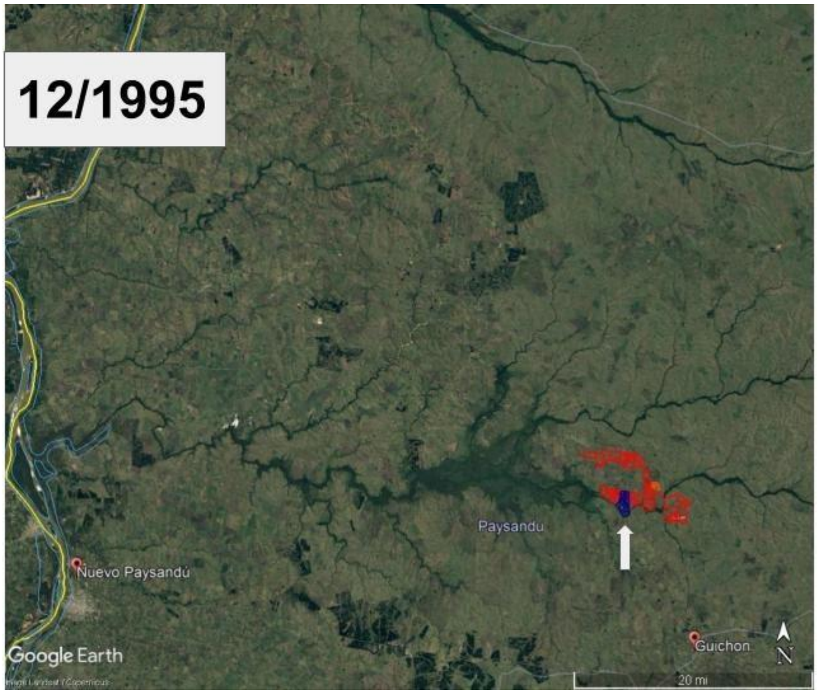

Figure 2a. Red conglomerate shows the Colonia Juan Gutiérrez. Point of the white arrow shows the blue outline of the property hosting pixel 3B. Dark green area represents the state of the forestry plantation expansion in December of the year 1995.

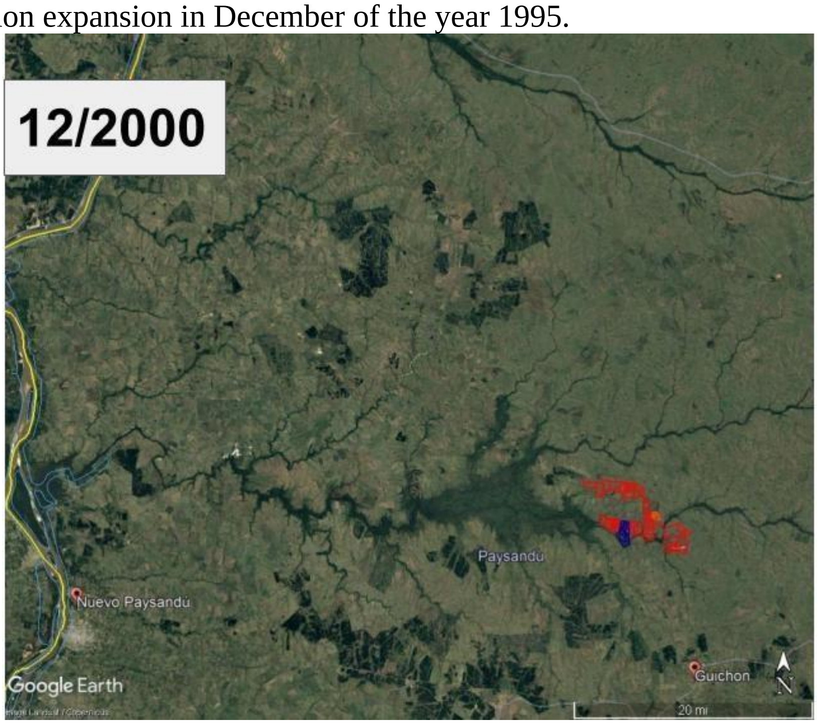

Figure 2b. Red conglomerate shows the Colonia Juan Gutiérrez. Dark green area represents the state of the forestry plantation expansion in December of the year 2000.

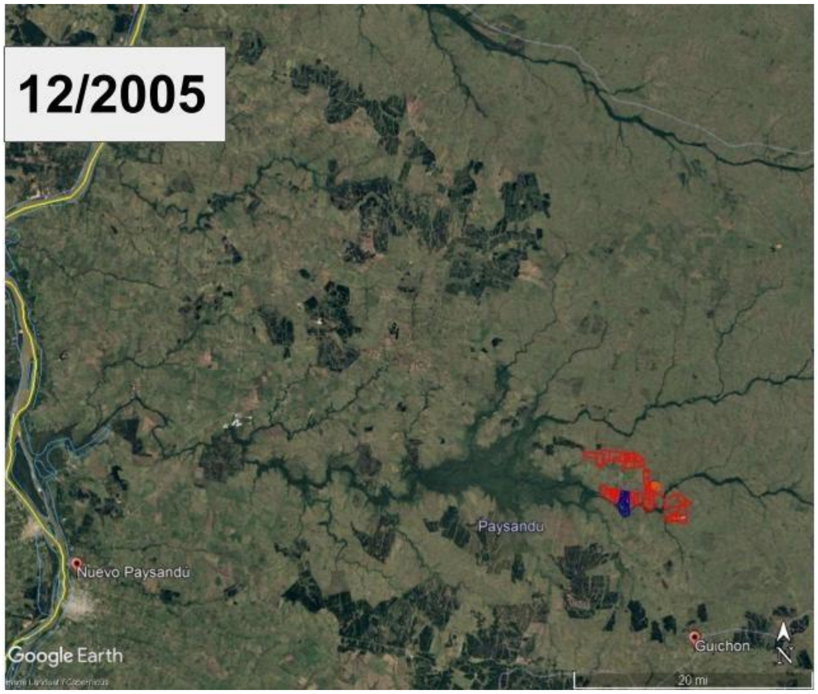

Figure 2c. Red conglomerate shows the Colonia Juan Gutiérrez. Dark green area represents the state of the forestry plantation expansion in December of the year 2005.

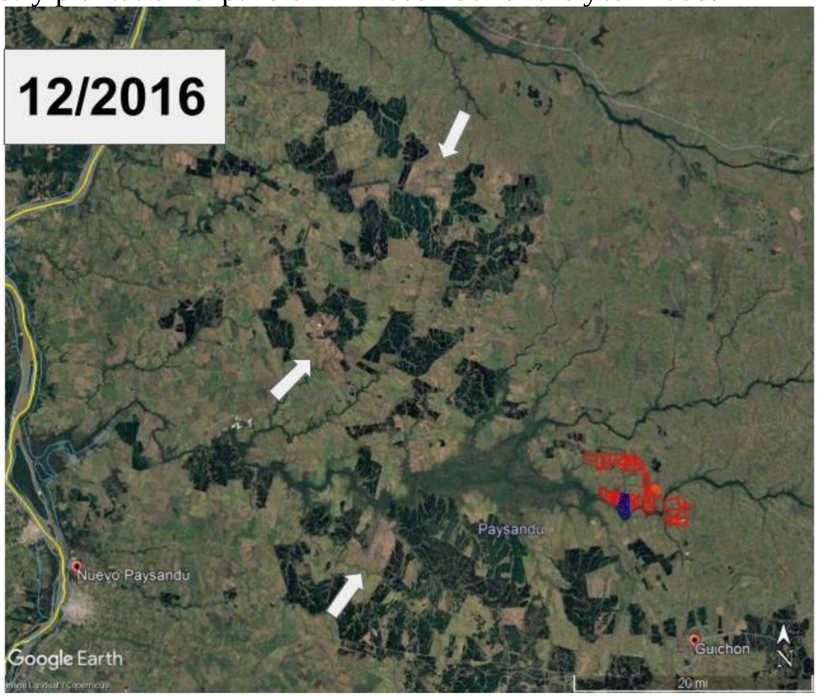

Figure 2d. Red conglomerate shows the Colonia Juan Gutiérrez. Dark green area represents the state of the forestry plantation expansion in December of the year 2016. The points of the white arrows show light brown areas of clearcutting in forestry plantations.

Figure 2. Historical satellite imagery showing the expansion of the forestry plantations around the Rincon de Perez conservation area and the Colonia Juan Gutiérrez. Images produced by the TEAM tool in December of the years 1995, 2000, 2005, and 2016.

Land Cover Composition and Distribution

	Zoom Level 1 Outermost area	**Zoom Level 2**	**Zoom Level 3 Innermost area**
Forestry Plantations	-Deciduous broadleaf forests -Mixed forests	-Closed shrublands	-Grasslands -Evergreen broadleaf forests -Woody savannas -Savannas
Rincon de Perez Conservation Area	-Deciduous broadleaf forests	-Mixed forests	-Evergreen broadleaf forests
Properties in the Colonia Juan Gutiérrez	-Grasses	-Savannas	-Woody savannas -Evergreen broadleaf forests

Table 1. Land cover type distribution in the forestry plantations, the Rincon de Perez conservation area, and the properties in the Colonia Juan Gutiérrez. Analysis completed using the *map bounding box* and the *zoom* feature of the Google Earth Engine TEAM tool.

Figure 3. (left) Land cover distribution in the Colonia Juan Gutiérrez and location of the 3B woody savanna pixel. Savannas (yellow pixels) and woody savannas (brown pixels) in the riparian area delineate the Queguay Grande River located south of the Alianza-associated properties. (Right) Legend: IGBP land cover classification system.

The vegetative land cover composition of the forestry plantations displayed deciduous broadleaf forests and mixed forests in the outer area, the same as in the outer layer of the conservation area, indicating a transition between both of these areas (Forseth, 2010). This may indicate that certain characteristics distinguish the forestry plantations from the conservation area, and it may suggest that the integrity of the conservation area is being preserved despite the proximity to the forestry plantations. At the same time, the core of both of these areas share evergreen broadleaf forests. More interesting is that the Colonia property that was chosen as a sample for more detailed investigation, shown in blue outline at the point of the white arrow in Figure 2a, also displays evergreen broadleaf forests in the woody savannas of its riparian area in the Queguay Grande floodplain (Figure 3). This property was chosen because it hosts an entire pixel (3B) of woody savanna on its grounds, unlike the other properties that only host a portion of such pixels. Having identified this pixel with such characteristics will allow us to trace land cover changes that could potentially affect the Colonia properties in the long term. Additionally, this finding could aid in identifying if woody vegetation found in the forestry area might be spreading to other non-forested areas.

Dynamics in the watershed may have an important role in the dispersal of these invasive evergreen species. The land cover analysis using the IGBP classification system shows the land cover of the riparian area outlining the Queguay Grande River as savannas (Figure 3). Within these savannas' pixels 1B, 2B, 3B, 1M, 2M, and 3M are identified as woody savannas. According to the IGBP classification system, land cover identified as woody savannas have forest canopy cover between 30%-60%. A more detailed analysis of the land cover composition of pixel 3B, which is the only pixel entirely located within a property, determined that the forestry composition was that of non-native evergreen broadleaf forests. It bears recognizing that the MODIS data used are at a resolution of 500 m pixels, and with each pixel covering such a large area, land cover in each pixel is likely more diverse than the datasets present, since each pixel may be better described as a "mixel". Each pixel's value, however, should reflect the majority land cover.

Rancher Survey and Interviews

The demographic survey indicated the participation of two females, five males, and two sets of married couples. Two participants were in the 20-40-year-old age range, four were in the 41-60-year-old age range, and three participants were 61 years of age or older. The highest level of education among the participant pool was that of technical school and university. Educational background included three participants with post-secondary education (university or technical school), three participants with secondary education (high school), and four participants with primary education. Length of land tenure and management included one participant with less than 9 years, three participants with 10-19 years, two participants with 20-29 years, and three participants with 30-39 years. Five participants used rotational grazing and four used continuous grazing in their properties. All participants reported that their properties were not considered large compared to the rest of the properties in the area; three were considered medium-sized (454-1002 has), and six were considered small (200-424 has). According to the participant's answers to the demographic survey, most properties had a greater extent of a combination of native and planted native grasses (100-900 has) compared to native forests (1-102 has). Livestock herd sizes ranged from 0-1650 sheep and 150-500 cattle. No goats were raised by the participants.

Participant Code	Gender	Age	Education	Time Managing Property (yrs)	Grazing Type	Total Property Surface (has)	Perceived Property Size	Native/ Natural Grasses Surface (has)	Native Forests (has)	Number of Sheep	Number of Cattle	Distance to Closest City (km)
ur001	F	41-60	Primary school	20-29	Rotational	398	Small	320	74.8	700	200	31
ur002	M/F	41-60	Primary school	20-29	Rotational	424	Small	404	13	Not provided	380	30
ur003	M	20-40	Primary school; technical school	<9	Rotational	270	Small	198	1-2	400	400	35
ur004	M	>61	University	10-19	Continuous	230	Small	190	-	0	160-180	30
ur005	M/F	41-60	Primary school	30-39	Continuous	454	Medium	-	35	1650	190	25
ur009	F	>61	High school	30-39	Rotational	1002	Medium	900	102	0	450-500	18
ur015	M	>61	Primary school	10-19	Rotational	200	Small	100	30	80	250	12
ur016	M	41-60	High school	30-39	Continuous	653	Medium	653	50	900	350	35
ur018	M	20-40	High school	10-19	Continuous	385	Small	350	-	700	150	35

Table 2. Results of the demographic survey completed by the nine participants in this study.

Targeted grazing: Building paddocks or adding paddocks for rotational grazing was welcomed by four producers of whom two would definitely implement this practice, especially if outside funding was available that covered the installation costs. Four producers were not sure or were neutral about this practice, and one producer did not want to build paddocks or add paddocks on his/her property. Three producers would keep paddocks or areas protected from grazing temporarily for winter forage, seed bank, or wildlife refuge, and two would definitely adopt this practice. Two producers were neutral or not sure about adopting this practice, and two would not adopt this practice even if funding was available. Five producers were unsure or neutral about adopting mobile electric fences, and four producers said they would not adopt this practice regardless of available funding. Prescribed burning: The use of prescribed burning was unanimously rejected by all participants. Mowing: One participant was neutral or unsure about the use of mowing to manage unwanted vegetative growth. Eight participants would not adopt this practice even if funding assistance were available.

The most common response to the adoption and implementation of the practices presented in this interview was a “no” to four out of five practices regardless of available funding. The next most common participant response was neutral or not sure about adopting and implementing four out of the five practices presented in this interview regardless of available funding. All producers selected “definitely not” (-2 ranking) for the use of prescribed burning. Two targeted grazing practices (*Building paddocks for grazing rotation* and *Keeping paddocks/areas protected from grazing temporarily for winter forage, seed bank, or wildlife refuge use*) were most often selected as +1 and +2 rankings if funding were available to assist adoption. Ranking results are summarized in Table 3.

	I would be willing to adopt the following practices if there were no funding limitations.				
Practice	**Definitely yes (+2)**	**Yes (+1)**	**Not sure/ Neutral (0)**	**No (-1)**	**Definitely not (-2)**
Prescribed burning	0	0	0	0	9
Building paddocks for rotation	2	2	4	1	0
Keeping paddocks/areas protected from grazing temporarily for winter forage, seed bank, or wildlife refuge	2	3	2	2	0
Mobile electric fences	0	0	5	4	0
Use of machinery, like lawn mowers to trim patches of unwanted vegetation	0	0	1	8	0
TOTAL	**4**	**5**	**12**	**15**	**9**

Table 3. Rancher survey results showing the number of ranchers willing to adopt a practice regardless of the cost. Prescribed burning and use of lawn mowers to trim unwanted vegetation were the practices least likely to be adopted.

The chart below shows a synthesis of the themes, examples, and explanations provided by the producers regarding the practices presented during the rancher interview and debriefing interview. Some examples or explanations are included in more than one practice as the producers combine different practices to manage woody encroachment vegetation.

Use, Attitudes, Beliefs, and Barriers Regarding Woody Encroachment Practices	
Prescribed Burning	
Themes	**Explanation**
Fire use	-Used to burn but not anymore because the area was too close to the forest. -Producer has used it only a few times.

Perceptions about fire	-Fire produces more damages than benefits. -Fire destroys the seeds and roots and deeply damages the soil -Fire leads to undesirable vegetation growth. -Fire is worse than herbicide applications because it damages the seed and the soil.
Barriers to fire use	-The high regulation of fire is due to the establishment of forestry plantations. They are trying to protect the forestry plantations. -Fire should be applied before it rains to prevent burning the soil. -Fire is prohibited from December to the end of April in Uruguay. -Fire is used to clear land and expand grasslands. -There are other ways to improve the grassland.
Building Paddocks for Rotation	
Themes	**Explanation**
Building additional paddocks for Rotational grazing producers	-Already have paddocks and want to build more / A common obstacle is the lack of financial resources -Satisfied with the current number of paddocks on the ranch. -Space is lacking for additional paddocks. -Construction of additional paddocks should be done to improve forage condition (rotational grazing).
Building paddocks for continuous grazing producers	-Continuous grazing does not use paddocks therefore it is not possible to implement some practices promoted by the Alianza nor some of the other practices for woody encroachment management. -Producers have already installed paddocks for livestock organization by categories (Calves, heifers, cows, bulls, steers), or winter forage (verdeo).
Perceptions of paddocks and woody encroachment management	-Implementation of woody encroachment management practices is more efficient if the producer has paddocks. -Practices can be combined with paddocks to decrease woody encroachment. This includes turning the soil with machinery, then introduce livestock grazing to manage woody species -Some producers already use paddocks for woody encroachment management (specifically for caraguata and chirca)
Protected areas reserved for winter forage, seed bank, and/or wildlife refuge	

Themes	Explanation
Producers prefer not to adopt or are unable	-There is no interest in adopting this practice (elder producer). -Producers lack space in their property.
Producers have adopted this practice, or a similar practice, in the past	-This practice has been adopted but winter conditions prevented its use as a seed bank. -Livestock feeding during winter *verdeo* rotational grazing which is a combination of extra nutritious vegetation for livestock grazing and it is not solely composed of native grasses.
Producers are interested in adopting the practice	-Details are lacking on how to properly implement this practice. -Producer has never implemented this practice but would consider it.
Protecting paddocks/areas from grazing and woody encroachment management	-Some producers are using this technique with woody encroachment species for winter grazing of cattle, not necessarily sheep because sheep do not eat the targeted woody species (caraguata).
Mobile electric fencing	
Themes	**Explanation**
Mobile electric fence use	-Keeping paddocks protected from livestock grazing for later use. -Organizing livestock according to soil types where cattle feed on the deeper soil and sheep in the shallower soil. -Complementing livestock management during rotation schedules. -Sporadic use during special events. -Livestock feeding during winter *verdeo* rotative grazing which is a combination of extra nutritious planted grasses and vegetation for livestock grazing, and it is not solely composed of native grasses.
Reasons for producers not using an electric fence	-Prefers traditional fencing although it is more expensive. -Requires more financial resources and labor to implement in areas where woody encroachment impinges on the fence.
Use of machinery to trim unwanted vegetation	

Themes	Explanation
Machinery is unnecessary	-Livestock can eat overgrown and unwanted vegetation. -The management of woody encroachment vegetation should not need the regular use of machinery.
Producers have the equipment, but it is not used regularly	-Equipment is available but rarely used. It has been used twice in 37 years of property management
Perceptions of equipment for woody plant management	-Use equipment to turn the soil and eliminate woody vegetation (caraguata). -Equipment should be used as a last resource to clear woody encroachment vegetation but it is not a preferred method - Equipment should be used in extreme cases where woody encroachment is overgrown. It should be used to turn the soil for 1-2 years, and then use livestock to manage woody encroachment regularly.
Herbicide application for woody encroachment management	
Themes	**Explanation**
Perceptions about herbicide applications	-Herbicide applications pollute water resources and are costly (informal conversation) -Herbicide applications are not enough to manage woody encroachment vegetation. This treatment should be done in conjunction with other practices. -Some producers hire staff to specifically apply herbicides to woody encroachment vegetation (need additional help).
Positive aspects of herbicide applications	Herbicide applications are less harmful than fire because only harms the vegetation and not the seed nor the soil.

Table 4. Use, attitudes, beliefs, and barriers to adoption of woody encroachment practices as revealed in interviews.

DISCUSSION

The land cover composition of pixel 3B was determined to be evergreen broadleaf forests. A more detailed analysis of the land cover composition in the other pixels is needed to determine if those also host evergreen broadleaf forests. However, the location of pixel 3B may provide insights about what may happen with woody encroachment coming in through the riparian area of these properties. The riparian area of a property is often partially protected during livestock grazing, and sometimes is not grazed if there is danger to livestock from seasonal flooding (*personal communication*). Lack of sufficient grazing pressure may create appropriate conditions for woody vegetation to increase, especially when management of the riparian area is reduced or neglected because it is not being utilized for grazing. Increased extent and maturity of woody plants makes management more costly and complicated. A more serious situation involves the encroaching of invasive woody vegetation species like *Pinus spp*. and *Eucalyptus spp*. found in the forestry plantations (Archer et al., 2017; Barger et al., 2011). These exotic species are known to have negative impacts on faunal and floral biodiversity, acidification of the soil and impacts on the water cycle of the watershed (chapter 3).

Detailed cover analysis indicated that forestry plantations, the Rincon de Perez conservation area, and ranches all contained broadleaf evergreen forests. Water use efficiency (WUE), gross primary productivity, and evapotranspiration in the evergreen broadleaf forests of the forestry plantations was similar to that of the evergreen broadleaf forests in the riparian areas of the properties (chapter 4). The WUE of grasses in all three areas of interest were also analyzed for potential resemblance, this analysis showed a similar trend where the WUE of the grasses located in the forestry plantations resemble that of the WUE of the grasslands in the Colonia properties (chapter 4). These results indicate that the integrity of the grassland ecosystem in the properties may be compromised by the potential encroachment of the invasive evergreen species located in the forestry plantations. Additional studies are needed to follow woody encroachment over time and determine the source of the evergreen species in the properties.

The demographic survey provides an interesting context for the analysis of the rancher interviews. It is important to acknowledge the participation of females in the sorting and interview processes. Female voices provided different perspectives, a balance to the conversation, and validity to the responses related to the accessibility of certain practices. In addition to the female property owners participating in this study, the females in the two sets of married couples had an active role during the interviews. Another factor to acknowledge is the fact that there were continuous grazing producers in the participant pool, allowing livestock to graze a pasture for an extended period of time, and rotational grazing producers participating in this study (*Grant County Grazing and Pasture Management*, n.d.). This is indicative of the diversity of producers working with the Alianza. Although the Alianza advocates adoption of rotational grazing practices, they also work with ranchers who do not wish to install additional paddocks. This is an important factor in the adoption of targeted grazing for woody encroachment management as a number of these practices require paddocks. It is also important to note that none of the producers interviewed owned goats, which can play a pivotal role in managing woody encroachment but require additional management costs, time, and effort (Walker, 2013).

Although prescribed burning is widely used in the grasslands of the USA, it is strictly regulated in several countries in the Southern Cone of South America. In the case of Uruguay, strict enforcement of fire laws seems to have been effective in eliminating prescribed burning being considered as a woody plant control option as evidenced in the reaction of producers during interviews. Attitudes towards use of prescribed burning were overwhelmingly negative and all participants ranked the practice as one they were least likely to use. While participants seemed to have some information regarding prescribed burning, it was rarely associated with its positive role in maintaining healthy grassland ecosystems. Responses were mostly associated with the negative effects that fire might have when used for woody encroachment management. An interesting point was raised regarding the strict enforcement of the fire law where the participant associated it with the incoming forestry plantations in the country. In the late 1980s, Uruguay provided financial incentives for afforestation efforts to diversify the rural economy of the country (Chescheir et al., 2008). Several national and foreign companies took on this opportunity and in order to protect these investments, the fire use law could have been enforced more stringently.

> *"...I think that [the fire use law] came because of the foresters... to protect the foresters [forestry companies]. I think it came mainly because of the issue of deforestation, there are so many foresters, so many forested fields that …In Uruguay there is not so much burning of fields to clean up [unwanted vegetation]. Little is burned. Although there are many dirty fields [fields with woody vegetation], down in the Colonia. I think that Uruguay in general burns very little" Participant ur005 (translated by author).*

Prescribed burning was sometimes compared to the use of herbicide applications for the eradication of unwanted vegetation. This was especially the case when referring to chirca *(Acanthostyles buniifolius)* (Rodriguez et al., 2018) and caraguata (*Eryngium pandanifolium*) (Museo Nacional, n.d.), which are the most common woody species encroaching on the participant's properties. Herbicide applications were perceived more positively than prescribed burning as it was believed that it was less harmful to surrounding vegetation. Although herbicide application was marginally perceived as a better option than prescribed burning, ranchers gave several reasons for not choosing it as a preferred method of woody plant control. Reasons given included: 1) potential for herbicides to pollute water resources 2) substantial cash outlays are required to hire help and apply the herbicide effectively; and 3) herbicide application alone is probably insufficient to eradicate woody encroachment problems.

> *"You burn the grass to the roots, it's like a herbicide but worse. no? Because fire burns even the seed in the ground and herbicide, for example, does not burn the seed. The herbicide burns the grass but the seed, I think it does not affect". Here the chacrero [similar to a hired gardener] uses herbicide while planting, but it is not used for anything else" ur005 (translated by author)*

One practice promoted by the Alianza is the use of equipment to trim unwanted vegetation. Participants also interpreted this practice to involve the use of large equipment to turn the soil for woody encroachment management. This practice was perceived as unnecessary given that livestock grazing could often achieve the same control and eight of nine ranchers stated they would not use mechanical control methods even if funding was available. Some participants reported having sporadically used heavy machinery to turn the soil to target woody encroachment. The investment needed to rent or purchase such machinery is only feasible if supplemental funding is available, without which this practice would be inaccessible for several participants. However, participants seemed to agree that such investment may be necessary if the woody encroachment of chirca and caraguata was overgrown and out of control. On this specific point, it was suggested that a proper treatment would involve the turning of the soil and the introduction of livestock to prevent the resurgence of such vegetation.

> *"No [I won't adopt this practice because], that's why you go in with the cattle" ur015*

> *"In our case, the machine is something that is rarely used. Here we have used it one or two times to clean a paddock that had a lot of caraguata. It is a triangle and we cinch it to the tractor to break the caraguata when it appears" ur005*

> *"Its use is not ideal. I'm going to do it here because ... I have no choice. I would prefer fixed [fenced] wiring and leave the chircas and do not cut anything. I'm*

going to do it but I'm going to do it out of necessity, but it's not because I like it. It's not what I like the most" ur004

"caraguata is what we have… it grew in three paddocks when I lost animals. I turn that [soil] upside down for a year or two and then I fill it with animals" ur002 (translated by author)

Interview participants, both those rotationally grazing and those continuously grazing, explained their considerations when contemplating adding additional paddocks. Alianza ranchers utilizing continuous grazing had paddocks in their properties but not necessarily for rotational grazing. Their paddocks were used to organize livestock categories and sometimes for *verdeo*, which is a paddock growing a combination of extra nutritious vegetation for livestock grazing in the winter. Some producers who were already practicing rotational grazing were unable to fit more paddocks on their property and others had financial limitations. These obstacles may be reflected in the fact that four out of nine participants were unsure about implementing this practice, and four agreed they might implement it if funding sources were available. Some producers were already using paddocks for livestock management and woody encroachment management.

"I like that [practice], you see. But I would not [adopt] it for rotation because I do not do [rotational grazing] ...When we [first] came here, there were [only] a few paddocks. Afterward, all [the paddocks you see there] we made, more than anything to keep the categories of animals apart" ur005

"Yes, without a doubt this is my goal [to build paddocks], what happens is that it is not easy. You said there is no funding limitation? I am willing to put on the work, if I can fence, it would be remarkable. If the money is fixed, the better" ur004

"I can build small paddocks with high loads [of livestock] and in a day or two of grazing they will break all [the chirca]. I can control the chirca, I'm not interested in cutting the chirca. If I handle the [livestock] load, in the long run, I

can control the chirca... the chirca is not going to bother me" ur004 (translated by author)

In addition to building paddocks, the other practice that received a yes and definitely yes to its adoption and implementation was the temporary isolation of areas or paddocks for winter forage, wildlife refuge, or seed bank. Dedicating an additional paddock for this purpose was perceived as an obstacle to some producers. At the same time, those producers who lacked information on this practice were interested in getting additional details to determine the feasibility of adoption and implementation. Some producers were already using this practice and seemed to be using it for one of the three purposes outlined. For example, some producers were implementing this practice either with *verdeo* and others with woody species like caraguata, which was grazed especially by cattle as the producers had concluded that sheep would not eat this woody vegetation.

"yes, this I have done but this forage is for the seed bank. I let one paddock grow for the seeds from September to November. For a seed bank, you have to close it and keep it sheltered from grazing so that you have a seed bank, this builds memory [in your grassland]" ur001

"In wintertime, for example, when the pasture is scarce ... I place one of my livestock categories in a caraguata paddock because the sheep does not eat it. But sheep would eat other unwanted vegetation" ur002

Lastly, producers believed electric mobile fences were useful for management purposes but were only sporadically used as an accessory fence as traditional fences are preferred, especially in problematic areas with overgrown woody species. These perceptions were reflected in the fact that most respondents were uncertain about adopting this practice even if funding were available.

"[I use the mobile fences] Precisely, to isolate areas or paddocks for the winter or to prioritize certain [livestock] categories and feed them" ur003

"Well, we have electrical fencing, you see, but we don't have that much either. I do not like it very much. I have it because it is cheaper, but I like the other [traditional] fencing system better" ur005

"I have no choice, because I cannot put an electrical wiring in that chircal [a field full of chirca], so I have to use traditional fencing" ur004

In summary, TEAM tool analyses suggest the possibility that evergreen broadleaf species located in the forestry plantations and those located in the riparian area of the sample property share certain physical characteristics, namely WUE, GPP, and ET (chapter 4). This may indicate that evergreen forest species from the forestry plantations may be entering the riparian area of this property. This is worrisome given that these are invasive eucalyptus and pine species. If these invasive woody species encroach on the grasslands used for grazing it may endanger not only this grassland ecosystem but also the economic basis of these ranching communities. Organizations like the Alianza work towards conserving the native grasses of the Southern Cone and the continuation of the gaucho way of life by promoting practices that sustainably manage woody encroachment while taking into account the ecological, social, and cultural contexts, and legal frameworks.

Rancher interviews showed that two of the four practices promoted by the Alianza were viewed favorably by producers of the Colonia Juan Gutiérrez who already associate with the Alianza. These practices were building of paddocks or adding paddocks and the temporary isolation of areas or paddocks for wildlife refuge, seed banks, or winter foraging. Electric mobile fencing was not received positively but instead producers were unsure or neutral about this practice even if there was funding available. On the other hand, the use of machinery for unwanted vegetation management was perceived as useful only in extreme situations when woody encroachment was overgrown. Herbicide applications were perceived as costly, polluting, and not efficient in the eradication of unwanted vegetation. Prescribed burning was the only practice rejected by all producers. The negative connotation of prescribed burning seems to be attached to concerns that escaped fire (wildfire) could affect the investments of national and international forestry companies.

Although only two promoted practices were selected as definitely acceptable by participants, it was evident that they have often tried combinations of the practices presented here and are already using easily accessible management strategies, such as targeted grazing, to manage woody encroachment. Using the practices that are welcomed in this community and that are compatible with traditional sheep and cattle production may be sufficient to improve the management of woody vegetation in this community. A new approach has been proposed, which views woody encroachment management from a coexistence rather than an eradication perspective. This coexistence approach includes ranchers, cattle, grasslands, forest, woody species, and other biodiversity. This approach may be unusual and peculiar to western eyes but in the Uruguayan context it may be an option that could become a part of everyday ranching practices. This approach appears to be a viable option given the limited tools available to ranchers when dealing with woody encroachment. The idea of coexistence over eradication, although already practiced by some of the producers interviewed, is emerging in circles of agricultural authorities where it has been received with both caution and curiosity about what additional research may indicate.

Knowledge and use of range management concepts such as targeted and multispecies grazing to achieve specific management goals are evident in participant responses, regardless of educational background, which may be evidence of the traditional ecological knowledge in the region. Examples of how this knowledge is being incorporated into ranching operations of the Colonia Juan Gutiérrez include:

> *"Here all 450 hectares are used. Even the part that grabs the forest, the cattle walk into the forest" ur005*

> *"But here we have more cattle than sheep. Agronomists recommend having both livestock together. Right now, for example, that we came out of this rough winter that we had, the sprouting of the field was difficult because it begins to sprout, and the sheep eat it. You must work [sheep and cattle] separately " ur005*

> *"I use selective use; I work with cows and sheep. It is not necessary to [provide special] feed for sheep because it eats differently from the cows. I kill the caraguata with a certain category [of livestock] and the discard that the others left was left for other categories" ur002*

> *"Here I kill the caraguata with animals. I use selection. One paddock with this livestock species ... And I don't use fire. caraguata is what we have here. I lost animals and three caraguata paddocks grew. I turn that [soil] with a machine for a year or two, I kill the whole caraguata, and then I include animals. But for that [caraguata eradication] you have to have animals. Bad management happens when you use herbicide and take out the animal load" ur002*

In September of 2020, Mr. Marcelo Pereira, an agricultural engineer working with the Plan Agropecuario, the Uruguayan extension office, presented the idea of co-existence with native woody plants at the Expo Prado 2020, a trade show and agricultural fair where technological innovations and new agriculture-related ideas are showcased. In his presentation "*Inclusión de Módulos Arbustivos en Ganadería Sobre Campo Natural: Una Alternativa Posible*?" ("*Inclusion of Woody Modules in Natural Grassland Cattle Ranching: A Possible*

Alternative?" Translated by the author), Mr. Pereira argues that typical Uruguayan sheep and cattle ranching operations could be used to manage woody encroachment instead of eradicating it. He proposed the idea of coexisting instead of eradicating as a long-term and sustainable solution to woody encroachment in Northern Uruguay.

Pereira drew on his experience as an agricultural extension agent in northern Uruguay to present empirical and scientific data, demonstrating the past and future relationship of ranchers with chirca, a common woody species of the area belonging to the Eupatorium family. Mr. Pereira argued that chirca has been used historically in the region for livestock refugia in areas where tree cover is unavailable, leading to fewer deaths during extreme weather events in both winter and summer months. At the same time, Mr. Pereira reported that livestock that had spent winters in chircales, or chirca-filled plots, enjoyed better health and greater weight gains than those that did not. The physical structure of chirca shrubs are believed to decrease wind velocity and increase the localized temperature in the winter, providing conditions for the emergence of winter forage. In the summer, chirca shrubs protect the understory forage, shading it from sun radiation and lowering the temperature (Pereira, 2020). This physical functionality might apply not only to chirca but also to other woody species with similar characteristics.

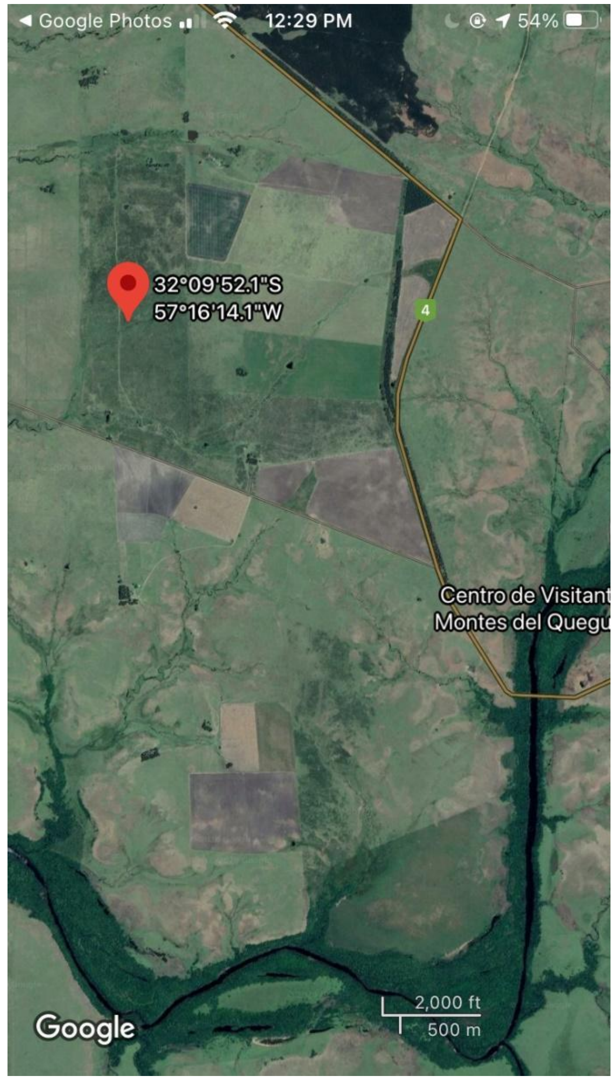

Photo 1 (top): Evidence of chirca woody encroachment in the riparian area of a stream. Photo by author.

Photo 2 (bottom): Evidence of chirca woody encroachment. Photo by author.

Photo 3: Location of woody encroachment pictured on photo 1 and 2.

Major winter events with high wind, low temperatures, and high precipitation have been shown to have significant effects on the vegetation of this area (Pereira, 2020) (chapter 3). Importantly, large numbers of livestock have succumbed under these weather conditions. The winter events of 2013 left lasting memories in the ranching communities of northern Uruguay as thousands of newborn lambs perished due to the combination of harsh weather conditions and the lack of vegetative refugia. This event and the acknowledgment that climate change will make things worse have prompted conversations among stakeholders and governmental organizations about ways to provide refugia to livestock during winter and summer (Pereira, 2020).

The academic sources presented by Mr. Pereira demonstrated that shrubs can have positive effects on Uruguayan grasses and therefore have value in addition to their benefits as refugia (Fernández et al., 2014; Fernández & Altesor, 2019; Pezzani et al., 2011). The literature suggests that ultimately, the management of areas with woody encroachment will require both sheep and cattle grazing. The desired amount of environmental (*i.e,*. wind, temperature, radiation) effects on the understory vegetation caused by shrubs can be controlled by livestock density and season of use. Sheep are known to graze on the chirca bushes and prefer the young shoots. Therefore, to control this woody shrub, the correct stocking rate for sheep would need to be determined to obtain the desired control of young chirca (Fernández et al., 2014; Fernández & Altesor, 2019; Pereira, 2020; Pezzani et al., 2011). With this in mind, Mr. Pereira offers ideas on land cover distribution to benefit livestock, the producer, and floral and faunal biodiversity.

The overarching design, which some of the Colonia producers are already using, involves the preservation, or creation, of shrub mottes within pastures. Mr. Pereira also suggests taking advantage of the presence of these woody encroached areas to create enclosures for emergency grazing, paddocks with regulated grazing for woody encroachment management, and areas with livestock transit pathways similar to distributions used for silvopastoralism. A more controversial, and longer-term idea is to introduce a woody species, like Chirca into a livestock raising operation. To enjoy all the benefits associated with this introduced vegetation, 4-5 years should pass before the vegetation has grown to the desired size. Mr. Pereira closed his argument by highlighting the fact that this approach is especially beneficial now that the weather conditions are getting more extreme due to climate change.

Climate change in Uruguay is predicted to increase summer temperatures by 1.5-degrees C, and increase the magnitude of thunderstorms, both of which can have detrimental effects on livestock health (Aldave, 2013; “Un establecimiento en Salto perdió 1500 animales, entre varios perjudicados,” 2013; “Malo Para Todos: Muerte de Ovejas Por Temporal,” 2013; “Mortandad de corderos a causa del clima,” 2018; Pereira, 2020). At the same time, other trends are creating enhanced conditions for woody encroachment. The increase of atmospheric CO_2 and precipitation are catalysts for the overgrowth of woody species. In Uruguay, cattle raising has increased whereas sheep raising has decreased from 26 million heads in 1991 to less than 6 million in 2020, with increasing overgrazing and depletion of potential fuel for prescribed burning. Ranchers in the region covered in this study report that traditional sheep stocking rates for managing grown woody encroachment species are now insufficient for control (Pereira, 2020). These changes are used in support of co-existence and a reduction in the effort expended towards complete control (Pereira, 2020).

Pereira admits that there are several questions that still need to be answered before these ideas are officially introduced to the livestock raising community. More research is needed to thoroughly understand the growing cycle of chirca to properly tailor management plans. Additional research is needed to determine the correct stocking densities for woody encroachment control. Managing for vegetative homogeneity in grasslands is culturally rooted in Uruguayan society and that may be the most difficult factor to overcome in order to increase the receptivity of these ideas (Pereira, 2020). Additionally, when woody encroachment is allowed to occur, there is a concurrent increase in undesirable vegetation species, and additional research on controlling these species is needed (Pereira, 2020). Options other than woody plants exist for sheltering and feeding livestock during inclement conditions, and the cost/benefits of various options needs to be explored (Pereira, 2020).

CONCLUSION

Targeted grazing for woody encroachment aligns with the cultural and socio-economic context of the Colonia Juan Gutierrez, and under certain circumstances may have beneficial consequences to ecosystem services and conservation goals. For these reasons, serious efforts should be launched to educate ranchers on the proper use of targeted grazing, potential negative impacts to native species conservation, and the most appropriate practices to achieve both cultural and ecological benefits. Additionally, an increase in the implementation of targeted grazing could prepare ranchers in the Colonia for the projected increase in woody encroachment resulting from the conditions created by climate change. More importantly, becoming efficient in its implementation could prevent the encroachment of exotic species like pine and eucalyptus, which can potentially migrate down the watershed from the expanding forestry plantations to the ranches in the Colonia.

Ranchers interviewed for this study are receptive to practices that align with the coexistence approach to woody encroachment management. A number of them have adopted and implemented practices promoted by the Alianza that mesh well with targeted grazing strategies and would make targeted grazing easier. Some ranchers are already using a targeted grazing approach to managing woody plants, indicating a cultural alignment with this strategy. Ranchers strongly preferred using livestock species common to the region for this purpose, and were aware of stocking rates, season of use, and livestock diet preferences when planning grazing for woody plant control. Prescribed burning is culturally unacceptable and highly regulated. Biological control using insects was not mentioned in interviews or encountered in the regional literature reviewed for this paper. Missing from the scientific literature is research on the inclusion of a woody vegetation component in the landscape for providing beneficial microclimate effects (shade, temperature, and wind mitigation) for plants and livestock. Chircales, or fields filled with chirca, were most often mentioned in this context.

Determining rancher use, attitudes, beliefs and barriers is useful in selecting and presenting practices that are acceptable to the ranching community, thus making agricultural and conservation organizations such as the Alianza, AUGAP, and the Plan Agropecuario more effective and efficient when choosing which practices and strategies to promote. Identification of practices currently unacceptable but holding great potential for woody plant control, such as prescribed burning, can be investigated through research and demonstrations for local ecosystem validity and possibly lead to future educational efforts.

References

Aldave, M. A. (2013, September 19). Sumarían más de 10.000 los ovinos muertos en Tacuarembó. *Todo El Campo*. http://www.todoelcampo.com.uy/espanol/sumarian_mas_de_10000_los_ovinos_muertos_en_tacuarembo-15?nid=9043

Alianza del Pastizal. (2017b). *Iniciativa de Conservación de los Pastizales Naturales del Cono Sur de Sudamérica*. Alianza Del Pastizal, La Carne Que Defiende Las Aves. http://www.alianzadelpastizal.org/noticia/alianza-del-pastizal-la-carne-que-defiende-las-aves/

Archer, S. R., Andersen, E. M., Predick, K. I., Schwinning, S., Steidl, R. J., & Woods, S. R. (2017). Chapter 2: Woody Plant Encroachment: Causes and Consequences. In *Rangeland Systems* (pp. 25–83). Springer Nature.

Bailey, D. W., Mosley, J. C., Estell, R. E., Cibils, A. F., Horney, M., Hendrickson, J. R., Walker, J. W., Launchbaugh, K. L., & Burritt, E. A. (2019). Synthesis Paper: Targeted Livestock Grazing: Prescription for Healthy Rangelands. *Rangeland Ecology and Management*, *72*, 865–877.

Barger, N. N., Archer, S. R., Cambell, J. L., Huang, C. Y., Morton, J. A., & Knapp, A. K. (2011). Woody plant proliferation in North American drylands: A synthesis of impacts on ecosystem carbon balance. *Journal of Geophysical Research: Biogeosciences*, *116*(3).

Blumberg, R. L., & Cohn, S. (2016). *Development in Crisis: Threats to Human Well-Being in the Global South and Global North*. Routledge.

Chescheir, G. M., Skaggs, R. W., & Amatya, D. M. (2008). Hydrologic Impacts of Converting Grassland to Managed Forestland in Uruguay. *Improving Water Quality and Environment Conference Proceedings*. 21st Century Watershed Technology, Concepcion, Chile. https://www.srs.fs.usda.gov/pubs/ja/ja_chescheir005.pdf

Coll, J. (2019). *Temporal Evapotranspiration Aggregation Method (TEAM)*. http://www.hydroshare.org/resource/7f43d1ff46d4403495427c59c0e1d790

Culliney, T. W. (2005). Benefits of Classical Biological Control for Managing Invasive Plants. *Critical Reviews in Plant Sciences*, *24*(2), 131–150.

DiTomaso, J. M., Monaco, T. A., James, J. J., & Firn, J. (2017). Chapter 13: Invasive Plant Species and Novel Rangeland Systems. In *Rangeland Systems* (pp. 429–463). Springer Nature.

DGDR/MGAP. (n.d.-a). *Ganaderos Familiares y Cambio Climático*. Dirección General de Desarrollo Rural. http://www.mgap.gub.uy/unidad-ejecutora/direccion-general-de-desarrollo-rural/institucional/llamados/vigentes/ganaderos-familiares-y-cambio-climatico

DGDR/MGAP. (n.d.-b). *Más Inclusión para el Desarrollo Rural*. Dirección General de Desarrollo Rural. http://www.mgap.gub.uy/unidad-ejecutora/direccion-general-de-desarrollo-rural/institucional/llamados/vigentes/inclusion-rural

DGDR/MGAP. (n.d.-c). *Más Valor a la Producción Familiar*. Dirección General de Desarrollo Rural. http://www.mgap.gub.uy/unidad-ejecutora/direccion-general-de-desarrollo-rural/institucional/llamados/cerrados/mas-valor-a-la-produccion-familiar

DGDR/MGAP. (n.d.-d). *Somos Producción Familiar*. Dirección General de Desarrollo Rural. http://www.mgap.gub.uy/unidad-ejecutora/direccion-general-de-desarrollo-rural/institucional/llamados/cerrados/somos-produccion-familiar

El temporal provocó la muerte de miles de ovinos en el norte. (2013, September 16). *El Observador*. https://www.elobservador.com.uy/nota/el-temporal-provoco-la-muerte-de-miles-de-ovinos-en-el-norte-201391622470

FAO. (2004). *FAO Corporate Document Repository*. What Is Local Knowledge? http://www.fao.org/docrep/007/y5610e/y5610e01.htm

FAO. (2017, May). *Foro Internacional: Modelos de Extensión y Servicios Rurales Para la Agricultura Familiar*. https://www.flickr.com/photos/75113635@N06/albums/72157680840657183/

Fernández, G., & Altesor, A. (2019). Differential responses of C3 and C4 grasses to shrub effects in a sub-humid grassland of South America. *Journal of Vegetation Science*, *30*(2), 203–211. https://doi.org/10.1111/jvs.12715

Fernández, G., Texeira, M., & Altesor, A. (2014). The small scale spatial pattern of C3 and C4 grasses depends on shrub distribution. *Austral Ecology*, *39*(5), 532–539. https://doi.org/10.1111/aec.12113

Fonseca, C. R., Guadagnin, D. L., Emer, C., Masciadri, S., Germain, P., & Zalba, S. martin. (2013). Invasive Alien Plants in the Pampas Grasslands: A Tri-National Cooperation Challenge. *Biological Invasions*, *15*, 1751–1763.

Forseth, I. (2010). Terrestrial Biomes. The Nature Education Knowledge Project. https://www.nature.com/scitable/knowledge/library/terrestrial-biomes-13236757/

Grant County Grazing and Pasture Management. (n.d.). K-State Research and Extension. https://www.grant.k-state.edu/grazing-pasture-management/

Guido, A., & Lopez Marsico, L. (2010). *Bosques del Río Queguay Grande: Relevamiento de Leñosas en la Colonia Juan Gutiérrez*. Cauba Flora Nativa. http://guayubira.org.uy/monte/seminario2010/Guido-Lopez-Queguay.pdf

Ibister, J. (2006). *Promises Not Kept: The Betrayal of Social Change in the Third World*. Kumerian Press.

Kremen, C., Iles, A., & Bacon, C. (2012). Diversified Farming Systems: An Agroecological, Systems-based Alternative to Modern Industrial Agriculture. *Ecology and Society*, *17*(4), 44.

Landini, F. (2016). Problemas de la Extensión Rural en América Latina. *Revista Perfiles Latinoamericanos*, *24*(47).

Landini, F. (2015). Extensión Rural en Paraguay: Análisis de Problemas y Concepciones de Extensión. *Investigación Agraria*, *17*, 87–97.

Landini, F., & Riet, L. (2015). Extensión Rural en Uruguay: Problemas y Enfoques Vistos por sus Extensionistas. *Mundo Agrario*, *16*.

Malo para todos: Muerte de ovejas por temporal. (2013, September 16). *Montevideo Portal*. https://www.montevideo.com.uy/Noticias/Muerte-de-ovejas-por-temporal-uc213643

Manning, S., & Miller, J. (2011). Manual, Mechanical, and Cultural Control Methods and Tools. In *Invasive Plant Management Issues and Challenges in the United States*. American Chemical Society.

McMichael, P. (2017). *Development and Social Change: A Global Perspective*. SAGE Publications.

MGAP. (n.d.). *Oportunidades y Proyectos: Ganadería*. http://www.mgap.gub.uy/oportunidades-y-proyectos/ganader%C3%ADa

Mortandad de corderos a causa del clima. (2018, August 21). *El Telégrafo*. https://www.eltelegrafo.com/2018/08/mortandad-de-corderos-a-causa-del-clima/

Museo Nacional. (n.d.). Eryngium pandanifolium. Album de Flora, Fauna y Antropología Del Uruguay.https://www.mnhn.gub.uy/museosdigitales/?mod=ficha&id=16&buscador=fichas_flora&buscadortodos=1

Ocaño, C., Boffano, A., Escudero, P., Garrido, J., Balero, R., Scaglia, C., & Gonzalez, A. (2018). *Manual de Manejo de Bosque Nativo en Uruguay. Actualización. Versión 2018* (1a ed.). Ministerio de ganadería, agricultura y pesca. https://www.gub.uy/ministerio-ganaderia-agricultura-pesca/comunicacion/publicaciones/manual-manejo-bosque-nativo#

Parera, A. F., & Carriquiry, E. (2014). *Manual de Prácticas Rurales Asociadas al Índice de Conservación de Pastizales Naturales (ICP) del Cono Sur de Sudamérica*. Aves Uruguay: Proyecto de Incentivos a la Conservación de Pastizales Naturales del Cono Sur.

Pereira, M. (2020, September 17). *"Inclusión de Módulos Arbustivos en Ganadería Sobre Campo Natural: Una Alternativa Posible?" ("Inclusion of Woody Modules in Natural Grassland Cattle Ranching: A Possible Alternative?")* [Plan Agropecuario]. Expo Prado 2020, Uruguay. https://www.youtube.com/watch?v=vytPk5-Jt7Q

Pezzani, F., Baeza, S., & Paruelo, J. (2011). Efecto de los Arbustos Sobre el Estrato Herbáceo de Pastizales. *Bases Ecológicas y Tecnológicas Para El Manejo de Pastizales*, *26*, 195–207.

Research, U. S. O. of E., Improvement, Center (U.S.), E. R. I., Education (U.S.), N. I. of, & Education (U.S.), N. L. of. (1978). *Resources in Education*. Department of Health, Education, and Welfare, National Institute of Education. https://books.google.com/books?id=fgQE6uYwDRwC

Restrepo-Osorio, D. L. (2015). *DEFINING PERCEPTIONS OF WATERSHED MANAGEMENT IN A GREAT PLAINS AND IN AN ANDEAN WATERSHED*.

Restrepo-Osorio, D. L., & Brown, J. C. (2018). A Q methodology application on disaster perceptions for adaptation and resiliency in an Andean watershed symposium: Water and climate in Latin America. *Journal of Environmental Studies and Sciences*, *8*, 452–468.

Roberts, J. T., & Hite, A. B. (2007). *The Globalization and Development Reader*. Blackwell publishing.

Rodriguez, E. E., Aceñolaza, P. G., Picasso, G., & Gago, J. (2018). *Plantas del bajo Río Uruguay: Árboles y Arbustos* (1st ed., Vol. 1). Comisión Administradora del Río Uruguay.

Saldaña, J. (2009). *The Coding Manual for Qualitative Researchers (3rd edition)* (3rd edition, Vol. 12). SAGE Publications.

Sayre, N., Carlisle, L., Huntsinger, L., Fisher, G., & Shattuck, A. (2012). The Role of Rangelands in Diversified Farming Systems: Innovations, Obstacles, and Opportunities in the USA. *Ecology and Society*, *17*(4), 1.

Shapero, M. W. K., Huntsinger, L., Becchetti, T. A., Mashiri, F. E., & James, J. J. (2018). Land Manager Perceptions of Opportunities and Constraints of Using Livestock to Manage Invasive Plants. *Rangeland Ecology and Management*, *71*, 603–611.

Thompson, D. (2016). Community adaptations to environmental challenges under decentralized governance in southwestern Uruguay. *Journal of Rural Studies*, *43*, 71–82. https://doi.org/10.1016/j.jrurstud.2015.11.008

USDA. (n.d.). *United States Department of Agriculture Farm Service Agency*. Conservation Programs: Prospective Participants/General Public. https://www.fsa.usda.gov/programs-and-services/conservation-programs/prospective-participants/index

Vanclay, F. (2004). Social Principles for Agricultural Extension to Assist in the Promotion of Natural Resource Management. *Austrian Journal of Experimental Agriculture*, *44*, 213–222.

Visión y Mision. (n.d.). Alianza Del Pastizal Para Conservar La Biodiversidad. http://www.alianzadelpastizal.org/institucional/mision-2/

Walker, J. (2013, December). Creating a "Super Juniper Eating Goat." *Ranch and Rural Living*. http://sanangelo.tamu.edu/files/2013/08/Super_Juniper_Eating_Goat.pdf

Wilcox, Bradford. P., Birt, A., Archer, S. R., Fuhlendorf, S. D., Kreuter, U. P., Sorice, M. G., Van Leeuwen, W. J. D., & Zou, C. B. (2018). Viewing Woody-PLant Encroachment through a Social-Ecological Lens. *BioScience*, *68*(9), 691–705.

Chapter 3: Rancher Perceptions of Water Resource Management Practices During Seasonal Variability in Uruguay's Queguay River Floodplain

INTRODUCTION

Ranchers in the Colonia Juan Gutiérrez, located in the Paysandú department, northwestern Uruguay, face numerous challenges in managing water resources in their ranching operations. A non-profit environmental organization, Alianza del Pastizal, is working to promote various water management practices to address these challenges. This chapter outlines what we know about these challenges, and then it details an investigation done to understand rancher perceptions of those practices to help Alianza del Pastizal determine which are the most likely to be adopted.

Properties in the Colonia have varying access to natural water sources; some properties are surrounded by water bodies, while others only have access to the Queguay Grande River. While both types of properties are affected by winter flooding, the magnitude of impacts increases with the number of surrounding water bodies. Ranchers rely on streams for livestock watering, but also need artificial water sources to provide safe, clean water throughout the year. During the summer, drought and evaporation due to high temperatures can reduce or dry up streamflow. During the winter, flooding can increase the risk of livestock drowning. Flooding is perceived to be an increasingly common phenomenon in the region. Flooding interferes with ranch management as roads and trails to parts of the ranch may become impassable and livestock care may be reduced. Ranchers prepare for flood events in several ways. Livestock can be moved away from flooded areas that are dangerous to their health, or restricted from accessing the stream in other ways, which is facilitated by the availability of artificial watering sources.

Flooding also impacts ranching families, leaving them isolated from neighbors and lacking access to road transportation for up to 10 days. Effectively, ranches become islands and they must hire boat drivers for transportation. In emergencies, when floods affect vulnerable residents, like pregnant women, the elderly, or children, the local emergency center relies on helicopters for evacuation, incurring a cost to the state. The Uruguayan National Emergency System coordinates public institutions for the protection of people, significant assets, and the environment from phenomena that may result in emergency or disaster situations. At the departmental level, the Departmental Emergency Committees seemed to be a prompt and reliable resource for ranchers in rural Uruguay, but there was also an underlying sense of community where neighboring ranchers were mentioned as resources in situations of need. Ranchers prepare for flooding events by laying in fresh produce from the nearby city of Guichón (Table 1) and by planning to butcher and consume beef from their own ranches.

Ranchers have grown accustomed to flooding events, but they have noticed an increase in unexpected, high-magnitude precipitation events, which create equally high magnitude floods. The impact of forestry plantations in the water dynamics of the Queguay Grande River watershed is increasing because these are the source of woody vegetation that encroaches on the areas of the watershed beyond the borders of the plantations. These floods are already having detrimental effects on the livelihoods of ranchers and their livestock, as significant numbers of livestock have perished during floods in the water bodies surrounding the Colonia Juan Gutiérrez.

Ranchers recognize the value of caring for natural water bodies like man-made ponds (*tajamar*), ravines, lakes, streams, rivers, creeks, watering holes, and wetlands, given that they depend on them for livestock watering. However, when these water bodies become dangerously flooded, ranchers have to opt for other watering alternatives. Typical artificial water sources include ponds, groundwater-fed stock tanks, windmill-fed waterers, Australian tanks, and others (Table 4), and are made from materials like steel, zinc, concrete, cement, or plastic, to hold water coming from a surface or groundwater source. If the location and the number of artificial waterers are properly located and installed and of sufficient number and size to meet livestock needs, the damage to livestock well-being resulting from flooding should be minimal. Conversely, ranchers without improved water distribution systems may find it difficult to manage their operation during the flooding season.

Plantation expansion

Several headwater streams in the lower watershed of the Queguay Grande river have been converted to forestry plantations. Based on previous studies, it can be expected that these forestry plantations will increase or decrease water yields, based on harvesting and management practices (chapter 2). Storm peaks and floods will likely increase following harvest of the trees in forestry plantations, which may exacerbate flooding issues experienced by ranchers in the area. These effects will likely intensify with the expansion of these invasive woody species in the watershed. For this reason, it is important to ensure that the local conservation organizations work closely with ranchers in the Colonia Juan Gutiérrez to understand the variability in their perceptions and be able to provide the necessary tools to manage both woody encroachment and water resources in order to confront imminent changes (chapter 2).

Land cover change in the Queguay Grande River watershed, specifically the increasing expansion of forestry plantations through woody vegetation encroachment on the areas of the watershed beyond the borders of the plantations may affect water dynamics by increasing the magnitude of floods in the Paysandú. These floods are already having detrimental effects on the livelihoods of ranchers and their livestock, as significant numbers of livestock have perished during floods in the water bodies surrounding the Colonia Juan Gutiérrez. Forestry plantations in the area seem to be increasingly spreading (Figure 5), so future floods may be increasingly damaging due to the impact of various planting and harvesting practices of pine and eucalyptus.

Climate change

Climate change is another stress that ranchers must face in their operations, and they are aware of predictions of an increased magnitude of thunderstorms, flooding, and higher summer and winter temperatures. Extension agent and agricultural engineer Marcelo Pereira gave a talk during the Expo Prado 2020, a trade show and agricultural fair where technological innovations and new agriculture-related ideas are showcased. During his talk, Pereira talked about adaptation strategies to climate change and based his arguments on the prediction that in Uruguay the magnitude of thunderstorms and summer temperatures will increase. Both of these claims align with the predictions made by the Ranching, Agriculture, and Fishing Ministry of Uruguay (RAFMU), and reinforce predictions made approximately 12 years ago about increasingly violent precipitation cycles and warmer winters. Awareness on the part of both extension agents and ranchers about what to expect with impending climate change is a step forward to increasing the receptivity to adaptation practices in ranches of the Colonia Juan Gutiérrez.

According to the publicly available meteorological records for extreme precipitation events, from 1971 to 2012, the department of Paysandú has had a significant number of years with extreme precipitation events, which are defined as years with several days of precipitation where 50mm (2in) of rainfall or more were recorded (INUMET, n.d.-b). Figure 1 shows 1978 as the year with the greatest number of extreme precipitation days (9 days) followed by 1980, 1984, 1986, 1990, 2011, and 2012 with 8 days of extreme precipitation events (INUMET, n.d.-b).

Adaptive action

To assist ranchers in adapting to climate change, it is crucial for Alianza del Pastizal to understand rancher's perceptions of the conservation practices they promote in order to increase the likelihood of adoption and implementation of these practices. Understanding the variability of perceptions among the ranchers in the Colonia Juan Gutiérrez would allow Alianza to focus the allocation of the resources available, which in turn would increase rancher's adaptability and resilience to environmental changes.

The way in which ranchers in the Colonia Juan Gutiérrez manage their water resources varies according to variation in topography; properties surrounded by water bodies are likely more affected by the floods than those that are not. This is not the only characteristic, however, contributing to variation among ranchers participating in this study. Many ranchers face financial constraints to implement or increase the number of livestock water sources. The Uruguayan government has acknowledged the significant investment that water distribution systems require and have made subsidies available in the past. A number of ranchers in this study have used those subsidies, but they are now in need of additional help for the maintenance and repair of their distribution system.

Alianza del Pastizal, a non-profit environmental organization, began working with ranching communities from Uruguay, Paraguay, Argentina, and Brazil in 2006 to facilitate ranchers exchanging information, resources, and education. The Alianza acknowledges the ecosystem services provided by native grasslands like the "mitigation of climate change, floods, water quality, landscape, recreational and spiritual value", and the preservation of cultural traditions associated with the ranching landscape (*Visión y Mision*, n.d.). The water resource management conservation practices Alianza del Pastizal promotes help ranchers in diversifying their livestock watering options in order to reduce their dependence on flood-prone natural water bodies.

Governmental subsidies and progressive extension services provided by organizations like the Alianza del Pastizal, Asociación Uruguaya de Ganaderos del Pastizal, AUGAP (Uruguayan Association of Grassland Ranchers) or the Plan Agropecuario, have an essential role in providing information on available funding, assessing rancher's eligibility, and planning for the implementation or expansion of these practices if subsidies are awarded. The adoption, implementation, and even the expansion of these practices can provide ranchers with increased resilience to face future flooding seasons.

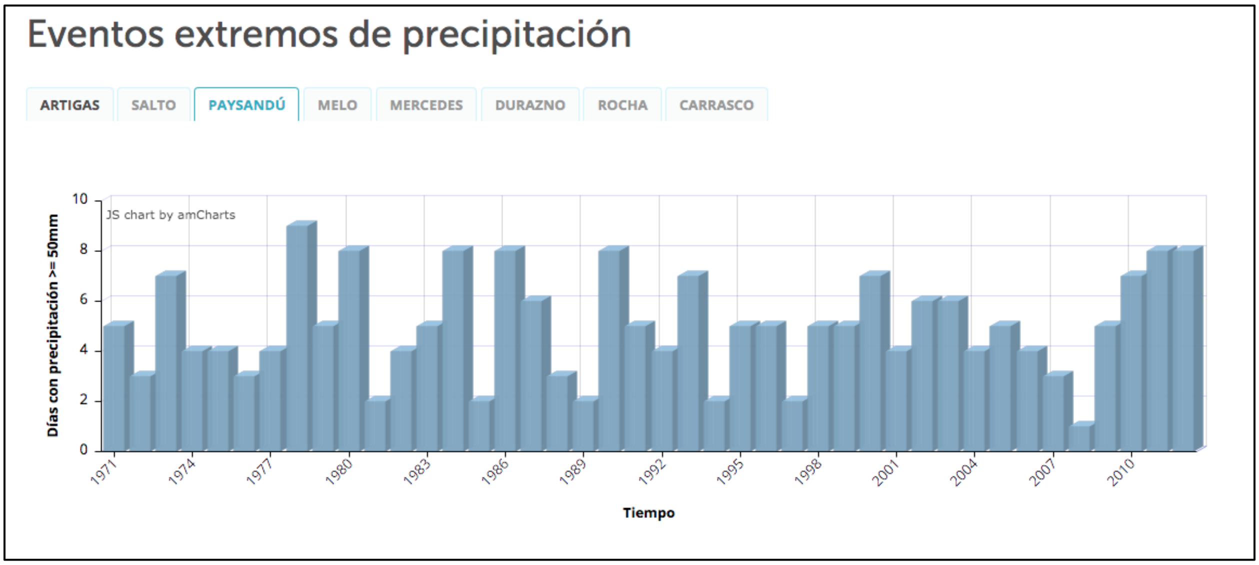

Figure 1. Extreme precipitation events in Paysandú from 1971 to 2012 showing days with precipitation >=50mm (2in) (INUMET, n.d.-b)

LITERATURE REVIEW

Impact of Forests on Water Dynamics

Forests are thought to reduce flooding by intercepting, evaporating, and transpiring rainfall. Additionally, forests act as a sponge to hold water and slowly release it to support baseflow, which is groundwater that eventually contributes to adjacent stream and river channels (Clark 1987; Laurence, 2007; Wilcox et al., 2008). The evapotranspiration and infiltration of rainfall for groundwater recharge by forests and woody vegetation helps to reduce the flood peak following precipitation events (Calder and Aylward, 2006; Wilcox et al., 2008). However, many variables may affect the forest-flood relationship, including local conditions, size of the precipitation event (FAO-CIFOR, 2005), and whether it is a natural forest or a managed forest.

The hydrological impacts of converting natural forests and grasslands to managed forests depend on a number of factors. In New Zealand, researchers have been monitoring the impacts of converting native forest and grassland to pine plantations since the mid-1970s. They found an average 65% increase in water yields (combined storm flows and low flows) for four years following harvest of the pine plantation. Tree growth brought water yields back to the levels of those of the natural forests within ten years (Fahey and Jackson, 1997).

Similarly, monitoring of water yields in the Tacuarembo River basin in Uruguay found that conversion of grassland/rangeland to managed pine plantations reduced water yields following storm events (chapter 1). Reductions were most pronounced during a storm event following a long dry period (Cheschier et al., 2008). In general, the conversion of grasslands to managed forests increases fluxes related to water evaporation and reduces water yields (Nosetto et al., 2011). Therefore, it can be inferred that the impact of forestry plantations on runoff and floods depends on the time since the last harvest, with more recently harvested forests resulting in greater water yields and larger runoff events. Additionally, and unlike managed forests, natural forests and grasslands have been shown to help with flooding resulting from small to medium sized precipitation events but not in floods resulting from high precipitation events (Bathurst et al., 2018; FAO-CIFOR. 2005; Laurance, 2007).

Forest plantation management practices will also affect water yields and flood peaks in streams. For example, managed forests may have features such as drainage ditches that increase runoff, resulting in larger storm peaks, in addition to an increase in sediment transfer in the watershed (Bathurst et al., 2018; Anderson et al., 1976). Forests managed with no natural vegetation in the understory have poor quality soil compared to soil under natural forests, which have more porosity, more infiltration and therefore low surface runoff and erosive events (Anderson et al., 1976; Calder, I. R., & Aylward, B., 2006). Forestry plantations located in headwater streams in a watershed may increase or decrease water yields, based on harvesting and management practices. Storm peaks and floods will likely increase following harvest of the forestry plantations, however, there is no consensus about the scale at which these effects occur (Bradshaw et al., 2007; Van DIJK et al., 2009). Some studies affirm that land cover changes that cause increased runoff upstream are more likely to become flooding events, spread downstream and have impacts at a large watershed scale (McCormick et al., 2009; Rogger et al., 2017) and at the same time, there are studies affirming the opposite (O'Connell et al., 2007).

Perception of Conservation Practices

Organizations providing subsidies or financial incentives for conservation practices should prioritize the understanding of producers' perceptions regarding these practices because perceptions dictate the likelihood of adoption and implementation. Generally, perceptions regarding agricultural practices are influenced by individual experiences and/or those of family members, friends or neighbors. Perceptions are variable at different scales and within different demographic groups. Although this idea seems self-evident, conservation programs trying to reach a wide variety of producers often hold generalized ideas of producer perceptions and goals. It is often assumed that producer decisions regarding the adoption of conservation practices are solely directed by goals of maximizing profit, but this is not always true (Bumbudsanpharoke et al., 2009). For example, producers who have an aversion to risks due to natural phenomena, like drought (Saarinen, 1966) may prefer to act proactively and utilize conservation practices especially if financial support is available (Houston & Sun, 1999). This variability among producers has shown the need for increased research regarding producer perceptions of proposed and current conservation practice policies and instruments (Bumbudsanpharoke et al., 2009).

Several studies involving producers and conservation programs acknowledged the need for a deeper evaluation of the perceptions among the individuals in their target population. In Louisiana, the lack of conservation practice adoption among ranchers was investigated to determine the reasons behind this outcome before approaching previously identified key ranchers (Gillespie et al., 2007). In Texas, Olenick et al. (2005; 259) highlighted the need for future research to determine ways to incentivize producers into participating in programs promoting the conservation of rangeland for ecosystem services. A study in Kansas investigated the causes influencing producers' decisions to invest in long-term conservation practices and concluded that understanding producers' perceptions is important for policy-related decision-making actors (Feathersone & Goodwin, 1993). The exploration of producers' perceptions in different contexts might aid policy makers in increasing the adoption and implementation of conservation practices.

Differences and commonalities among producers in various nations and within the USA demonstrate that assuming homogeneity in perceptions among producers is a failure in one-size-fits-all conservation programs (Greiner et al., 2009). A study in Australia examined producers' motivations for implementing conservation practices. They concluded that producers’ motives included leaving their land in good condition for coming generations (legacy), producing good quality food, looking out for the environment, to preserve their independence, and simply because they enjoy their lifestyle (Greiner et al., 2009). Similarly, a study in the USA concluded that the motivations for producers were also based on a sense of responsibility to future generations, but there was also a component of adoption of conservation practices to maximize profit and personal benefits (Greiner et al., 2009). Other studies in the USA, however, indicated a wide variation of motives for producers' adoption of conservation practices. A study of producers in Oregon indicated that their motives were based on moral obligations to be a good steward of the land (Rosenberg & Margerum, 2008). Kansas producers implemented conservation practices based on their enjoyment of watching wildlife and to provide this experience to future generations (Cable et al., n.d.).

Conservation efforts within watersheds and sub watersheds are challenging due to the variety of perceptions of what should be prioritized for improvement (Rosenberg & Margerum, 2008). Some producers who prefer to avoid disagreements that might arise from working with funding organizations prefer to implement conservation practices independently. Producers who opt to take this route are financially capable of implementation of the conservation practices of choice, however, producers in this situation are few. Producers who lack the financial means to cover the entirety of the cost, but are interested in conservation practices, often decide to apply for funding through conservation organizations. Subsidies and financial incentive programs generally provide part of the cost of a practice implementation with the producer still responsible for paying the remainder of the cost. Clearly there are producers unable to pay for their corresponding percentage and therefore cannot participate. In other cases, there are producers who can afford their part of the payment after financial incentives or subsidies but do not qualify for the conservation program because their property is not located in the priority area

(UWWRAPS, 2012). According to (Greiner et al., 2009) producer participation in conservation programs comes from a decision to pursue a lifestyle where conservation is a priority. states that If there is a change in perceptions towards a more positive receptivity of a conservation practice, the adoption rate will increase and eventually the need for technical assistance and financial incentives may decrease (Lynne et al., 1988).

Climate change in Uruguay

Climate change in Uruguay will deeply affect ranchers in the Colonia Juan Gutiérrez. In 2019, the Ranching, Agriculture, and Fishing Ministry of Uruguay (hereafter, RAFMU) carried out a statistical analysis to determine the climate change projection for Uruguay for 2070 (Bentancur et al., 2019). This projection was done to inform agricultural adaptation and mitigation efforts in the country. This report concludes that Uruguayan winters will become warmer with fewer frost days per year, summers will display more frequent heat waves with a rise in precipitation and extremely damaging precipitation events of more than 20mm(.8in) rainfall. Additionally, more extreme events will occur in southern Uruguay whereas northern Uruguay will remain stable (Bentancur et al., 2019). Polley et al. predict an increase in extreme weather events due to increased warming patterns which will lead to drought and heat waves (Polley et al., 2017).

STUDY AREA

Physical Context

Uruguay is part of the southern cone of South America and it is located on the southeastern coast of the continent between the latitudes 30° and 35° South. Topographic features include rolling hills with elevations up to 550m and grasslands/savannas biomes (Cheschier et al., 2008). According to the Koppen classification system Uruguay displays a mid-latitude humid subtropical to temperate climate (Cfa) with hot and humid summers with thunderstorms, and a mild winter with precipitation events (Cheschier et al., 2008). Uruguayan temperatures increase from the southeastern coast of the country to the northwestern departments (Figure 2). According to 1961-1990 records from the Uruguayan Meteorological Institute, the thirty-year normal temperature for the country is 17.5°C (63.5°F) with an average maximum temperature of 19°C (66.2°F) over the Artigas department, and an average minimum temperature of 16°C (60.8°F) over the Atlantic coast of the Rocha department (INUMET, n.d.-a). Precipitation in Uruguay takes the form of rain, with occasional hail or snow, and it tends to increase from southwest to the northeastern coast of the country (Figure 3). Annual average precipitation ranges from approximately 1100mm (43.3in) in the southwestern departments to approximately 1600mm(63in) in the Rivera department (INUMET, n.d.-a, https://www.inumet.gub.uy/)

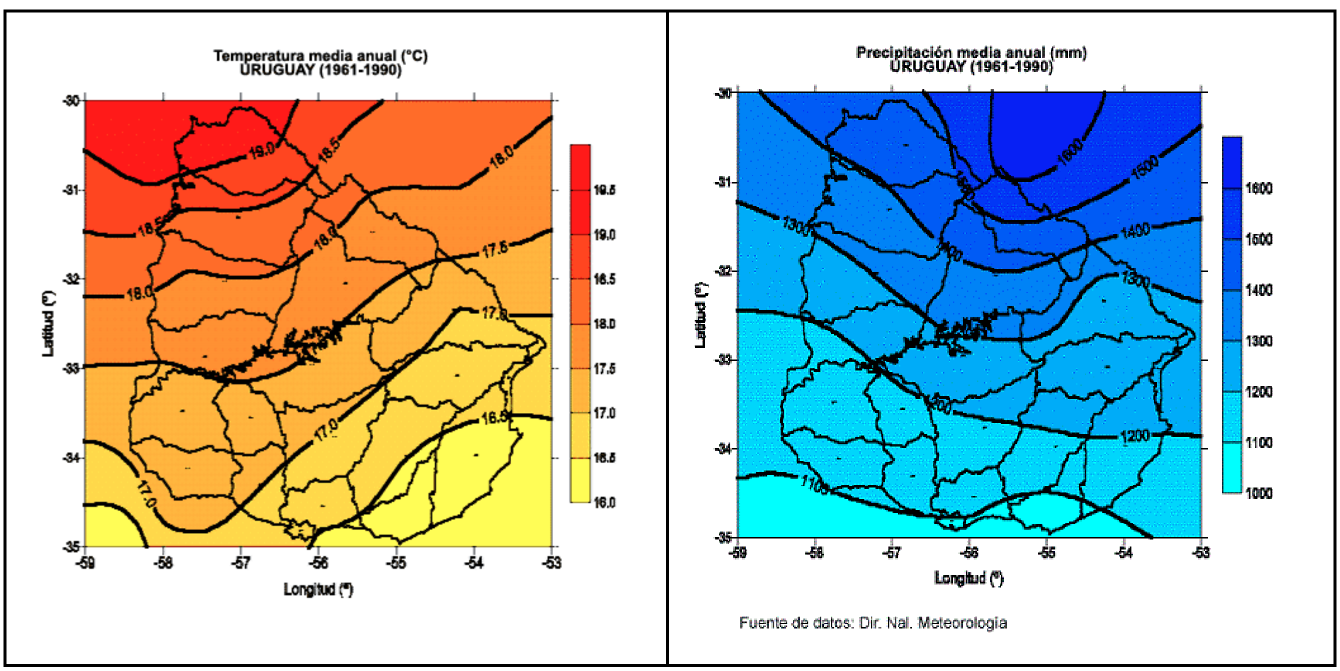

Figure 2. Uruguayan latitude and longitude. National annual average temperature in Celsius from 1961-1990 (left) and national annual average precipitation in millimeters from 1961-1990 (right) (INUMET).

The center of Paysandú department is approximately located at -32.34^{0} latitude and -58.0^{0} longitude in the northwestern area of Uruguay (Figure 4). According to records from 1961-1990, Paysandú's 30-year normal annual temperature is 17.9^{0}C (64.2^{0}F), with an annual maximum temperature of 42.4^{0}C (108.3^{0}F) and an annual minimum temperature of -4.5^{0}C (23.9^{0}F). The annual average precipitation in Paysandú during the years of 1961-1990 was 1218mm(48in) with a maximum 147mm(5.8in) in the month of March and a minimum of 70mm(2.7in) in the month of June (INUMET, n.d.-a).

The department of Paysandú is rich in streams and rivers, the majority of which serve as tributaries to the Queguay Grande river that runs from east to west. The Queguay Grande river watershed occupies a significant portion of the department of Paysandú (Figure 3) and runs through the Rincon de Perez conservation area and several forestry plantations before reaching the Uruguay River (Figure 3).

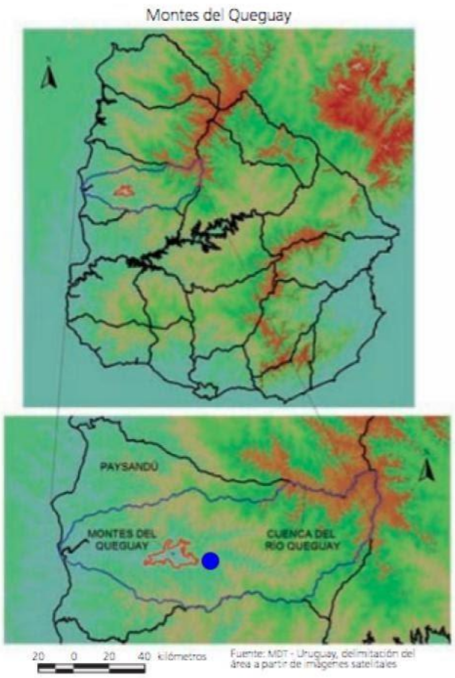

Figure 3. Orography and departments of Uruguay (top). Location of the Queguay Grande river watershed outlined in blue (bottom). Blue circle: study site (Grupo Creativos de Guichón et al., 2012)

Figure 4. Departments of Uruguay. Red star: location of Montevideo, the capital of the country. Blue circle: study site. mapasinteractivos.didactalia.net

METHODS

Conversion of Grasslands to Forestry Plantations

In order to understand the spatial extent of the spread of forestry plantations, we analyzed data on tree cover change using the Global Forest Watch (GFW) 2.0 web platform (www.globalforestwatch.org). The GFW is based on the Google Earth Engine platform (also used for the TEAMS model used in chapter 2) and uses Landsat satellite imagery to analyze global, annualized tree cover change at 30-meter resolution for each one of the years from 2000-

2019 (Hansen et al., 2013). We used the Paysandú department boundary from the Stanford Digital Repository (Hijmans & University of California, 2015), which was roughly analogous to the Queguay river watershed. The web platform analyzes tree cover gain and loss within the boundary and can be analyzed by individual years.

Rancher Survey and Interviews

Our objective is to determine which methods of livestock water supply, either artificial waterers or caring for natural water bodies for future use, are the most likely to be adopted by the ranching community. For this purpose, we interviewed nine producers who are members of the Alianza del Pastizal during the 2018 cattle ranchers meeting, which took place in Guichón, Uruguay. This event was organized by the Alianza del Pastizal and the Asociación Uruguaya de Ganaderos del Pastizal, AUGAP (*Uruguayan Association of Grassland Ranchers)*. Each year this ranchers meeting is hosted by one of the countries in the Alianza and their main objective is to facilitate the networking of producers from the four countries that the Alianza del Pastizal engages, namely Uruguay, Paraguay, Brazil, and Argentina. Additionally, this meeting highlights the latest sustainable cattle ranching research in the region with 15-minute talks, and at the end of the day, there is a barbeque of local sustainably raised beef and a cultural show. The meeting closes the following day with a field trip to a ranch that demonstrates sustainable cattle ranching practices promoted by the Alianza del Pastizal.

The practices presented in the interviews are those that are promoted by the Alianza del Pastizal as options for the ranchers to maintain their production while using native grasses. This analysis looks at how receptive the producers are towards the practices presented in the interviews, and if they are not already implementing them on their property, the possibility that they may adopt them in the future. Their association with the Alianza is based on an agreement to conserve the native grasses in their properties, however, it is important to note that although the participants in this study are associated with the Alianza, they have not necessarily adopted all practices promoted by this organization. The agreement with the Alianza is flexible because of the need to tailor this agreement to the needs of a variety of producers in the four countries that the Alianza represents (Uruguay, Paraguay, Brazil, and Argentina). Therefore, the management regimes of each property depend on the ecological, social, and cultural contexts as well as the legal frameworks of each location. While all participants in this study associate with the Alianza, it is evident that there is significant variability in their agreement with the Alianza, leading to the potential that they have different perceptions on the adoption and implementation of the practices presented in these interviews.

Before distributing the IRB approved survey[5] and interview materials, participants received a code for privacy purposes. Then they were asked to fill out a demographic survey which asked their gender, age, education, how long they have managed their property, grazing type, total property area, perceived property size compared to other properties in the area, the amount of area in native grasses, the size of the area of native forest, number of sheep, number of cattle, and how far they are located from the closest city. After this demographic survey was completed participants were asked to keep the following statement in mind: *I would be willing to adopt the following practices if there were no funding limitations.* Then participants received two 4” x 6” cards with one the following practices written on them: 1) Care for natural water bodies,

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[5] Record ID numbers: 23032287; 10218798; 23032288.

for example fencing out livestock for river bank protection, to use during extreme droughts (long-term care of natural water bodies for future use), and 2) strategic placement of water resources for livestock use (Parera & Carriquiry, 2014). The participants were then presented with a *Lona* (a cloth tarp) on which to place the 4"x 6" statement cards across a Likert scale (-2, +2) on the x-axis. Participants were asked to place the two cards on the Likert scale with the restriction that they could not put more than one card on either of the two extremes (-2 and +2) in order to make their priorities clear for this exercise. After the participants placed their two cards on the scale, they were asked to share their reasoning for placing the cards where they did on the Likert scale. The Q set administration process provides an intimate space for participants to reflect on their views and ideas while sorting the cards on the semi-normal distribution. The post-sort interview provides participants with an opportunity to articulate the reasons for the resulting sorting distribution. This is viewed as one last possibility for participants to change the card sorting and define how they want their perception to be represented in the Q sort pattern. Ultimately, the Q method helps participants to situate themselves in a perception group and to recognize the variation of perceptions among stakeholders (Restrepo-Osorio, 2015; Restrepo-Osorio & Brown, 2018)

Synthesis of Themes

Participants agreed to the audio recording of their interview responses during the request for oral consent for the interview at the beginning of the interview process. Interview recordings were transcribed in Spanish by a third party. Translation to English was not required since the author's (D.L. R-O) native language is Spanish, and it was crucial to analyze the interviews with the original cultural meanings, sayings, and other subjective information embedded in the original interview language. Interview responses related to each one of the practices listed above were moved to a different document for analysis. Responses were condensed into quotes, grouped into themes, and particular quotes that exemplified certain ideas were translated to English by the author (c.f. Saldaña, 2009).

RESULTS

Conversion of Grasslands to Forestry Plantations

From 2001 to 2012, the department of Paysandú gained 59.2kha (146,286 acres) of tree cover region-wide (Figure 5). It is estimated that 8.1% of the watershed is in natural tree cover; 6.9% is in tree plantations; and 85% is non-forest (Figure 6). Although the pine forest plantations are a small area of the watershed, they are spatially arranged to cover the majority of the headwater areas of the lower watershed tributaries (Figure 5). Headwater streams typically comprise at least 2/3rds of a stream network's total length and are important to maintaining hydrological connectivity and ecosystem integrity in the stream system (Freeman et al., 2007). Land use changes in headwater areas that alter runoff or nutrient loads can have amplified downstream effects (Freeman et al., 2007).

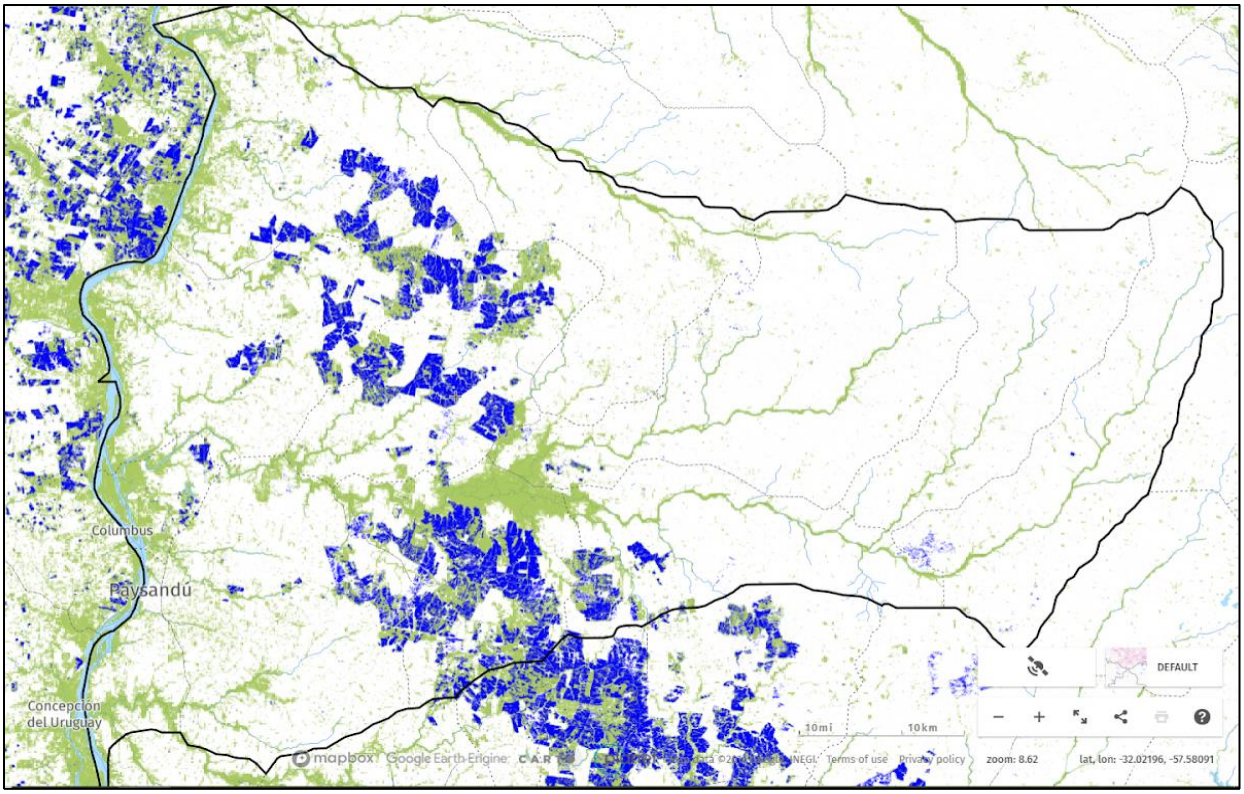
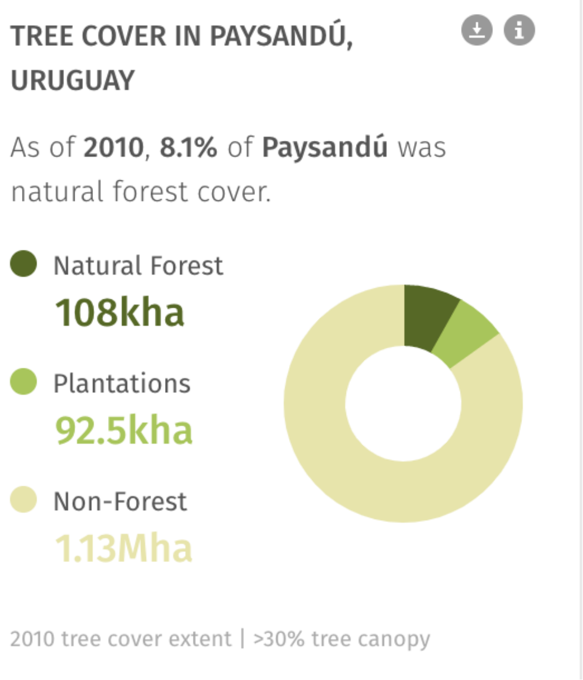


Figure 5. Global Forest Watch 2.0 analysis of tree cover gain for the Paysandú department from 2001-2012. Blue: tree cover gain from 2001-2012. Green: tree cover with >30% canopy density.



IGBP Land Cover Descriptions

Grasslands: lands with herbaceous types of cover. Tree and shrub cover is less than 10%.

Savannas: lands with herbaceous and other understory systems, and with forest canopy cover between 10% and 30%. The forest cover height exceeds 2m.

Woody savannas: lands with herbaceous and other understory systems, and with forest canopy cover between 30% and 60%. The forest cover height exceeds 2m.

Evergreen broadleaf forests: lands dominated by broadleaf woody vegetation with a percent cover >60% and height exceeding 2m. Almost all trees and shrubs remain green year-round. Canopy is never without green foliage.

Deciduous broadleaf forest: lands dominated by woody vegetation with a percent cover >60% and height exceeding 2m. Consists of broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.

Mixed forest: lands dominated by trees with a percent cover >60% and height exceeding 2m. Consists of tree communities with interspersed mixtures of mosaics of the other four forest types. None of the forest types exceeds 60% of the landscape.

Figure 6. (left) Tree cover extent in the department of Paysandú as of 2010 for woody savannas with >30% tree canopy. (right) IGBP Land Cover Descriptions.

Rancher Survey and Interviews

Participant Code	Gender	Age	Education	Time Managing Property (yrs)	Grazing Type	Total Property Surface (has)	Perceived Property Size	Native/ Natural Grasses Surface (has)	Native Forests (has)	Number of Sheep	Number of Cattle	Distance to Closest City (km)
ur001	F	41-60	Primary school	20-29	Rotational	398	Small	320	74.8	700	200	31
ur002	M/F	41-60	Primary school	20-29	Rotational	424	Small	404	13	Not provided	380	30
ur003	M	20-40	Primary school; technical school	<9	Rotational	270	Small	198	1-2	400	400	35
ur004	M	>61	University	10-19	Continuous	230	Small	190	-	0	160-180	30
ur005	M/F	41-60	Primary school	30-39	Continuous	454	Medium	-	35	1650	190	25
ur009	F	>61	High school	30-39	Rotational	1002	Medium	900	102	0	450-500	18
ur015	M	>61	Primary school	10-19	Rotational	200	Small	100	30	80	250	12
ur016	M	41-60	High school	30-39	Continuous	653	Medium	653	50	900	350	35
ur018	M	20-40	High school	10-19	Continuous	385	Small	350	-	700	150	35

Table 1. Results of the demographic survey completed by the nine participants in this study.

The demographic survey indicated the participation of two females, five males, and two sets of married couples, with two participants in the age range of 20-40, four of the participants in the age range of 41-60, and three participants 61 years of age or older. The highest level of education among the participant pool was that of technical school and university. Three participants received a high school education and four received primary school education. One participant had managed his property for less than 9 years, three participants had managed their property from 10-19 years, two participants had managed their property for 20-29 years, and three participants had managed their property from 30-39 years. Five participants used rotational grazing and four used continuous grazing in their properties. Participants reported that no properties were considered large compared to the rest of the properties in the area, three were considered medium-sized (454-1002 has), and six were considered small (200-424). According to the participant's answers to the demographic survey, most properties had a larger area of native grasses (100-900 has) compared to native forests (1-102 has). The numbers of sheep and cattle were mixed and ranged from 0-1650 sheep to 150-500 cattle. The distance to the closest city ranged from 12 to 35 kilometers (7.5 to 22mi) but most of the properties were located 30 to 35 kilometers (18.6 to 22mi) away from the closest city.

	I would be willing to adopt the following practices if there were no funding limitations				
PRACTICE	**Definitely yes (+2)**	**Yes (+1)**	**Not sure/ Neutral (0)**	**No (-1)**	**Definitely not (-2)**
Caring for natural water bodies to use during extreme droughts (long-term care of natural water bodies for future use)	2	1	4	2	0
Strategic placement of water sources for livestock use	0	4	5	0	0
TOTAL	**2**	**5**	**9**	**2**	**0**

Table 2. Rancher survey results showing the number of ranchers willing to adopt a practice regardless of the cost.

Some responses indicated the importance that the rancher is placing on the practice, and other responses indicate the need that the rancher has to adopt the practice, more so if it is funded. None of the ranchers definitely refused (-2) the adoption and implementation of the practices proposed in this study. However, there were two ranchers who indicated that they would not (-1) adopt these practices even if funding was available. One rancher reported that they are already caring for the natural water bodies in the property, therefore there was no need to receive incentives to adopt the practice. Another rancher pointed to the fact that this practice was not applicable as there is no direct access of livestock to the Queguay Grande River and there are no natural water bodies in the property. The neutral (0) category received the highest amount of ranchers responses with the practice *Care for natural water bodies for extreme drought events (To use for later during emergencies)* receiving 4 neutral responses, and *strategically placing waterers so that they are available to livestock* receiving 5 neutral responses. Ranchers who ranked the practice of *caring for natural water bodies* as neutral explained that they were already implementing this practice. Details were not provided as to how they were caring for these resources. Ranchers who ranked the *strategic placement of waterers* as neutral had needs that were greater than installing additional waterers in their property. This means that they had already installed as many waterers as they needed, or there are practices that need to be implemented before adopting additional waterers, for example the installation of paddocks or having access to electric fencing.

The positive receptivity of ranchers regarding both of these practices was evident in the +1 ranking category, which was the second highest after the neutral ranking (0). *Taking care of natural water bodies* showed to have a positive receptivity (+1) by ranchers who have significant dependence on natural water bodies for livestock watering. However, there was a particular emphasis on definitely (+2) needing to implement this practice associated with ranchers who recognized the importance of natural water bodies because their watering system completely depended on the direct access of livestock to natural water bodies. The *strategic placing livestock waterers* received four positive responses (+1). These responses were associated with ranchers who believe waterers are important for the proper functioning of a ranch, also ranchers who need to increase the number of waterers in their property, and ranchers who lack waterers and would adopt and implement waterers if funding is available.

Synthesis of Themes: Ranchers Receptivity and Perceptions of Water Resource Management Practices

Caring for natural water bodies to use during extreme droughts (long-term care of natural water bodies for future use)	
Themes	**Explanation**
High dependence on natural water bodies	-Rancher is completely reliant on surface water bodies as the main source of water for livestock
Natural water bodies used as complement to artificial waterers	-Rancher uses surface or groundwater sources to feed artificial waterers in their property via a mechanical pump or windmill -Ranchers property has surface water bodies but these dry up in the summer months
Strategic placement of water sources for livestock use	
Themes	**Explanation**
No additional artificial waterers needed	Rancher has sufficient artificial waterers in property
Needs financial assistance	-To implement or expand artificial waterers -To install infrastructure needed prior to water distribution installation

Table 3. Rancher interview results showing the themes and explanation to each practice presented.

Participant Code	Livestock Watering Method	
	Natural Water Bodies	**Artificial Waterers**
ur001	-River -Man-made ponds	-Groundwater fed stock tanks
ur002	-River -Streams	-Stock tanks -Groundwater fed stock tanks
ur003	-Man-made pond -Ravine	
ur004	-Intermittent streams -Man-made pond	-Groundwater fed stock tanks -Water reservoir tank

ur005	-Ponds -Wetlands -Ravines -Man-made ponds -Streams	
ur009	-Ravines -Rivers -Streams -Watering holes	
ur015	-Man-made pond -Creek -Watering holes -Pond Watering holes	-Stock tanks -Pond fed Australian tank -Stream fed solar panel pump Australian tank
ur016	-River	-Creek fed windmill stock tanks
ur018	-Pond -Ravines	-Groundwater fed stock tank -Windmill fed waterer -Australian tank

Table 4. Types of natural water bodies and artificial waterers used by each rancher for livestock water supply.

For the purposes of this study, we define natural water bodies as surface water that is not held in an artificial container, for example, man-made ponds (*tajamar*), ravines, lakes, streams, rivers, creeks, watering holes, and wetlands. Artificial waterers are those made from materials like steel, zinc, concrete, cement, or plastic, which hold water coming from a surface water source or ground water source, for example, Australian type tanks, windmill fed waterers, groundwater fed stock tanks, stock tanks. Australian tanks are called as such in the southern cone because they were originally designed in the 19th century Australia to provide water to sheep and livestock in dry and desert climates (*Tanque Australiano Para ganadería*, n.d.). All ranchers participating in this study used this terminology and they all varied in the combination of water sources used for their livestock (Table 4). This variation depended on the topography where the property is located and the financial resources the rancher has to adopt and implement artificial waterers. The ranking of both practices presented in this study reflect both the importance and dependence that ranchers have on the practice presented, and the financial need ranchers have for the adoption and implementation of the practice.

DISCUSSION AND CONCLUSIONS

Climate change in Uruguay is predicted to increase the magnitude of thunderstorms, increase floods, and increase summer and winter temperatures. These effects on their own are extremely problematic for floodplain ranching communities like the Colonia Juan Gutiérrez. However, this community is also under threat of land cover change from savannas to forests with the expansion of forestry plantations. Previous studies have shown that managed forests have serious effects on watershed dynamics by increasing storm peaks and increasing floods after tree harvesting. Moreover, the Colonia also faces unintentional woody encroachment of native and invasive woody species, which is predicted to increase due to climate change (chapter 2). These factors will compound the magnitude of the threats that ranchers in the Colonia Juan Gutiérrez will face in the future. Practices promoted by the Alianza del Pastizal should help ranchers in becoming more resilient, and preparing, adapting, and mitigating the damages that these events will cause.

The perceptions of ranchers regarding the *care of natural water bodies for extreme drought events or to use in future emergencies* split into those ranchers who associated the ranking score to the importance that they assign to the practice, and those who associated the ranking score to their need to receive financial incentives for adopting this practice. Therefore, there is significant variation on the scores assigned to this practice ranging from -1 to +2. Out of the nine ranchers interviewed four depend completely on natural water bodies to satisfy their livestock watering needs. However, two ranchers ranked this practice as +2, one rancher as 0, and one rancher as -1. Those ranchers that assigned the highest ranking to this practice did so to reflect the importance that healthy natural water bodies have in the success of their ranch in the short and long term. The other two participants associated the ranking of this practice to their need for financial support to adopt and implement this practice. These ranchers report to already be taking care of their natural water bodies and they prefer to use the financial incentives for other practices, like artificial waterers or paddock installation.

> *"In this property most of the waterers are natural water bodies.... Here it says to take care of the natural watersheds for extreme events of drought... Well, I think that is the most important thing, because without water animals do not live for two days, neither does grass. Now, if you do not have good natural water bodies, you may have to first put this one first: strategically accommodate washes so that they are available" ur005*

The perceptions of the ranchers who assigned lower ranking values to *caring for natural water bodies* were those who use this resource as a complement to their artificial water distribution system. One rancher assigned a +1 ranking to this practice, three ranchers assigned a 0 to this practice, and one rancher assigned a -1. The lowest ranking here was assigned by a rancher whose property is located in the floodplain of the Queguay Grande River but livestock are unable to access this resource. The rancher explains that it is too dangerous for livestock to get to the river and drink water directly from there. Therefore, all her water sources are groundwater fed artificial waterers. Those ranchers that ranked this practice as a 0 had natural water bodies that were unreliable during summer where they would become intermittent or completely dry up. Lastly, the participant that ranked this practice as +1 relies on the Amarillo stream, and intermittent streams to fulfill a portion of the livestock watering needs. However, this rancher also has artificial waterers in all paddocks of his property as an option for livestock watering supply and in case of drought or flooding.

"They are intermittent streams...They dry up in summer. To take care of the natural water bodies.... Yes, of course, always take care of those water bodies. That is what I have to do here because here the droughts are rough. You cannot..., no matter how much you take care of the natural water bodies, you have to resort to other watering options". ur004

"Yes, I am doing that [taking care of the natural water bodies] but they dry up for sure. That is why I made the Australian tank, which is fed by a pond. So I fence off the natural water bodies [to prevent livestock access and use artificial waterers for livestock water supply]" ur015

The perception and receptivity of the practice involving the *strategic placing of artificial livestock waterers* in a property divided into two groups. One group of ranchers have installed all artificial waterers needed to fulfill the watering needs of their livestock, and the other set of ranchers needed financial incentives in order to implement or expand their artificial water distribution system. It is important to keep in mind that for ranchers who practice rotational grazing, it is typically necessary to install fences for paddock distributions before installing the water distribution system. Therefore, some of these priorities are reflected in the responses provided by the ranchers in relation to this practice. Two of the ranchers who assigned a neutral (0) ranking to this practice did so because they have already installed their artificial water distribution system. Prior to establishing this system, both of these ranchers had to install fencing for paddocks and had to arrange a groundwater network to feed the artificial waterers in each paddock. Therefore, ranking this practice as neutral, demonstrates the importance that these ranchers associate with this practice but also shows the fact that there is no need for additional artificial waterers at the moment

"All paddocks have groundwater fed artificial waterers. I started installing paddocks in 2005. But the problem I had is that I had no water, until I arranged [for wells installation]". ur001

Ranchers who ranked this practice higher (+1) perceived this practice as important and lacked the financial means to implement it, therefore, if funds were available, they would prioritize the installation of artificial watering distribution systems. This practice received either a ranking of neutral (0) or a positive ranking indicating the positive receptivity of the rancher (+1). It is likely that the reason this practice was not ranked higher is that although ranchers acknowledged the importance of this practice, there are several arrangements perceived to deserve a higher ranking (+2) because they are needed before the installation of the artificial waterer distribution system. This was the case for a rancher who ranked this practice as neutral (0) because there are intermittent streams and a man-made pond in the ranch, but there is a need for artificial waterers to complement these water sources that become dry during the summer. However, the establishment of an artificial watering system is halted because paddocks for rotational grazing need to be installed first. The ranchers who ranked the *strategic placing of artificial livestock waterers* at +1 were interested in adopting and implementing this practice or expanding their current water distribution system. One of these ranchers had no artificial waterers in the property and solely relied on natural water bodies. Therefore, *caring for natural water bodies* was of priority as reflected in the ranking provided (+2), however, the *strategic placing of artificial livestock waterers* would be welcomed if funding was available, which was reflected in the +1 ranking.

> *"Having artificial waterers serves me better, especially since I am thinking of creating paddocks and there is no such thing as the artificial waterer. The man-made pond is complicated. Although I fence it off to cattle it dries up in the summer, and then if you let the cattle in, everything gets muddy. In winter there is water available. It is in summer that things dry up. In summer it is time to resort to another source, but in the winter, they drink from the natural water bodies"* ur004.

Ranchers in the Colonia Juan Gutiérrez have developed a special relationship with the natural resources nearby. During our interviews on more than one occasion they expressed protectiveness towards the Queguay Grande river and Rincon de Perez conservation area west of the Colonia, which is the largest forested area in Uruguay (Guido & Lopez Marsico, 2010). It seems like there is an association of the woody savannas with the ranching tradition and the Gaucho way of life, whereas the forested conservation area is associated with a deeper connection to nature, which was built through generational fishing expeditions in the depths of the forest (Grupo Creativos de Guichón et al., 2012). Both of these deeply meaningful places are linked by the flow of Queguay Grande river, and therefore there is a close relationship between the ranching community and this body of water. Ranchers in the Colonia Juan Gutiérrez have coexisted with the river and its fluctuations for generations, and therefore have established adaptive capacities to the seasonal flooding events. Adaptive capacity is defined as the "ability to adjust to potential damage or to take advantage of opportunities under climate change" (Joyce & Marshall, 2017). Adaptive capacity can be developed by plants, animals, humans, systems, and institutions, it is not always associated with monetary capacities, and it is always evolving with evolving changes.

It is important for Alianza to acknowledge that although ranchers in the Colonia have developed a strong adaptive capacity for water resource management under severe seasonal variability, they still need financial and technical aid to continue their adaptation to environmental change. This adaptive capacity involves caring for natural water bodies as these are a primary livestock watering source for the majority of ranchers, but also the increase or maintenance of strategically installed artificial watering systems used during droughts and floods. This study demonstrated the ability ranchers in the same Colonia have to accommodate variable hydrologic conditions and financial constraints. Making water available for livestock use requires a large financial investment that ranchers cannot always make. This is where Alianza may serve as a bridge between the ranchers in need for funding and organizations that can provide this help. Fortunately, Uruguayan governmental institutions have recognized this need and have made financial incentives and subsidies available for the installation of infrastructure associated with watering systems. Greater environmental challenges call for a greater adaptive capacity of conservation organizations and governmental institutions to provide additional guidance and financial support to ranchers in the Colonia. Each rancher's situation is different, and each rancher is at a different stage in the adaptation and implementation of practices that aid with water resource management in their property. This is the reason why understanding individual perspectives in the Colonia is imperative, because it allows for the tailored distribution of educational and financial resources available.

The ranching community that participated in this project has to worry about both livestock watering security and the expansion of woody vegetation encroachment. According to the woody encroachment management study developed for this dissertation, ranchers in this Colonia prefer to employ practices that emphasize a coexistence approach instead of an eradication approach (chapter 2). This approach aligns with the overall relationship that this community has with the natural resources that surround them, including the Rincon de Perez and the Queguay Grande river. The study in chapter 2 demonstrated that the woody encroachment management practice that best aligned with the cultural, ecological, and socio-economic contexts of the Colonia Juan Gutiérrez ranching community was targeted grazing. Taking this into consideration and acknowledging the fact that the installation of water resources management is a priority for this ranching community, it may be wise to analyze the interactions of implementing both of these practices for a more efficient use of available resources. For example, targeted grazing provides ecosystem services such as the maintenance of landscape heterogeneity, and in order to implement targeted grazing ranchers must install fencing for rotational grazing paddocks. This fencing is also a prerequisite for the installation of a watering distribution system, which provides additional benefits such as access to safe water sources for livestock during droughts and floods. Thus there are interrelated, multiple benefits to these practices.

Forestry plantation expansion in the headwaters of the lower Queguay Grande river watershed has the potential to exacerbate winter floods that deeply affect ranchers in the Colonia Juan Gutiérrez. Local conservation organizations promote practices that can help increase the adaptation and resilience of this community to the increase of extreme events predicted to rise with climate change. The practices explored in this paper include caring for natural water bodies for future use and the strategic placement of livestock watering systems. It was concluded that ranchers use natural water bodies, if available in their property, and transition or complement watering supplies with artificial waterers during dangerous flooding events or drought. Funding organizations should assess the receptivity and perceptions of ranchers to understand the variation in needs within this community. With this understanding, financial incentives and subsidies can be more efficiently distributed to cover the installation of infrastructure that may serve for the adoption and implementation of several practices at the same time.

A long-term assessment of what the Colonia Juan Gutiérrez may be needed to increase their adaptation capacities, which could be a productive endeavor for the governmental agencies that will provide future subsidies and financial incentives for ranchers. This task should be achievable due to the progressive methods that Uruguayan institutions use in face of climate change for project development in their ranching, fishing, and agricultural enterprises (chapter 2).

References

Aguadas y bebidas para ganadería. (n.d.). Tanque Australiano y Molino. Retrieved October 22, 2020, from http://www.tanqueaustraliano.com/

Anderson, H. W., Hoover, M. D., & Reinhart, K. G. (1976). *Forests and Water: Effects of Forest Management on Floods, Sedimentation, and Water Supply* (General Technical Report PSW-18). United States Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station.

Bathurst, J., Birkinshaw, S., Johnson, H., Kenny, A., Napier, A., Raven, S., Robinson, J., & Stroud, R.

(2018). Runoff, flood peaks and proportional response in a combined nested and paired forest plantation/peat grassland catchment. *Journal of Hydrology*, *564*, 916-927.

Bentancur, V., Molinari, M., Jones, C., & Oyhantcabal, W. (2019). *Proyecciones climáticas para Uruguay a 2040 y 2070 mediante la técnica de reducción estadística de escala en el marco del Plan Nacional de Adaptación del sector agropecuario* (p. 15). https://www.gub.uy/ministerio-ganaderia-agricultura-pesca/comunicacion/noticias/proyecciones-climaticas-para-uruguay-2040-2070-mediante-reduccion-estadistica

Bradshaw, C., Sodhi, N. S., Peh, K. S.-H., & Brook, B. W. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. *Global Change Biology*, *13*(11), 2379–2395. https://doi.org/10.1111/j.1365-2486.2007.01446.x

Bumbudsanpharoke, W., Moran, D., & Hall, C. (2009). Exploring perspectives of Environmental Best Management Practices in Thai Agriculture: An Application of Q-methodology. *Environmental Conservation*, *36*(3), 225–234.

Cable, T., Fox, J. A., & Rivers, J. (n.d.). *Attitudes of Kansas Agricultural Producers about Riparian Areas, Wildlife Conservation, and Endangered Species*- [SRP830.pdf (No. 830)]. Kansas State University.

Calder, I. R., & Aylward, B. (2006). Forest and floods: Moving to an evidence-based approach to watershed and integrated flood management. *Water International*, *31*(1), 87-99.

Chescheir, G. M., Skaggs, R. W., & Amatya, D. M. (2008). Hydrologic impacts of converting grassland to

managed forestland in Uruguay. In *21st Century Watershed Technology: Improving Water Quality and Environment Conference Proceedings, 29 March-3 April 2008, Concepcion, Chile* (p. 64). American Society of Agricultural and Biological Engineers.

Clark, C. (1987). Deforestation and floods. *Environmental Conservation*, *14*(1), 67-69.

Fahey, B., & Jackson, R. (1997). Hydrological impacts of converting native forests and grasslands to pine

plantations, South Island, New Zealand. *Agricultural and Forest Meteorology*, *84*(1-2), 69-82.

FAO-CIFOR. (2005). Forests and Floods: Drowning in Fiction or Thriving on facts? (FA0-CIF0R,

Bangkok, 2005).

Feathersone, A. M., & Goodwin, B. K. (1993). Factors Influencing a Farmer’s Decision to Invest in Long-Term Conservation Improvements. *Land Economics*, *69*(1), 67–81.

Freeman, M. C., Pringle, C. M., & Jackson, C. R. (2007). Hydrologic connectivity and the contribution of stream headwaters to ecological integrity at regional scales. *JAWRA Journal of the American Water Resources Association*, *43*(1), 5-14.

Gillespie, J., Kim, S. A., & Paudel, K. (2007). Why don't Producers Adopt Best Management Practices? An Analysis of the Beef Cattle Industry. *Agricultural Economics*, *36*(1), 89–102.

Greiner, R., Patterson, L., & Miller, O. (2009). Motivations, Risk Perceptions and Adoption of Conservation Practices by Farmers. *Agricultural Systems*, *99*(2–3), 86–104.

Grupo Creativos de Guichón, Club Queguay Canoas, & CEUTA-Centro Uruguayo de Tecnologías Apropiadas. (2012). *Memorias del Queguay: Aportes para plan de manejo del área protegida Montes del Queguay*. https://issuu.com/paysanducom/docs/memorias_del_queguay/61

Guido, A., & Lopez Marsico, L. (2010). *Bosques del Rio Queguay Grande: Relevamiento de Leñosas en la Colonia Juan Gutiérrez*. Cauba Flora Nativa. http://guayubira.org.uy/monte/seminario2010/Guido-Lopez-Queguay.pdf

Hansen M.C., Potapov P. V., Moore R., Hancher M., Turubanova S. A., Tyukavina A., Thau D., Stehman

S.V., Goetz S.J., Loveland T.R., Kommareddy A., Egorov A., Chini L., Justice C.O., Townshend J.R.G. (2013) High-resolution global maps of 21-st-century forest cover change. Science, 342, 850-853.

Hijmans, R. J., & University of California. (2015). *First-level Administrative Divisions, Uruguay, 2015* [Map]. Museum of Vertebrate Zoology. https://purl.stanford.edu/vw364wy7227

Houston, J. E., & Sun, H. (1999). Cost-Share Incentives and Best Management Practices in a Pilot Water Quality Program. *Journal of Agricultural and Resource Economics*, *24*(1), 239–252.

INUMET. (n.d.-a). *Estadisticas climatologicas*. https://www.inumet.gub.uy/clima/estadisticas-climatologicas

INUMET. (n.d.-b). *Eventos extremos de precipitación*. https://www.inumet.gub.uy/clima/recursos-hidricos/eventos-extremos-de-precipitacion

Joyce, L. A., & Marshall, N. A. (2017). Chapter 15: Managing Climate Change Risks in Rangeland Systems. In *Rangeland Systems* (pp. 491–526). Springer Nature.

Laurance, W. F. (2007). Forests and floods. *Nature*, *449*(7161), 409-410.

Lynne, G. D., Shonkwiler, J. S., & Rola, L. R. (1988). Attitudes and Farmer Conservation Behavior. *American Journal of Agricultural Economics*, *70*(1), 12–19. JSTOR. https://doi.org/10.2307/1241971

McCormick, B., Eshleman, K., Griffith, J. L., & Townsend, P. A. (2009). Detection of flooding responses at the river basin scale enhanced by land use change. *Water Resources Research*, *45*.

Nosetto, M. D., Jobbagy, E. G., Brizuela, A. B., & Jackson, R. B. (2011). The Hydrologic Consequences of Land Cover Change in Central Argentina. *Agriculture, Ecosystems and Environment*.

O'Connell, P. E., Ewen, J., O'Donnell, G., & Quinn, P. (2007). Is there a link between agricultural land-use management and flooding? *Hydrology and Earth System Sciences Discussions, European Geosciences Union*, *11*(1), 96–107.

Olenick, K. L., Kreuter, U. P., & Conner, J. P. (2005). Texas Landowners Perceptions Regarding Ecosystem Services and Cost-sharing Land Management Programs. *Ecological Economics*, *53*(2), 247–260.

Polley, H. W., Bailey, D. W., Nowak, R. S., & Stafford-Smith, M. (2017). Ecological Consequences of Climate Change on Rangelands. In D. D. Briske (Ed.), *Rangeland Systems: Processes, Management and Challenges* (pp. 229–260). Springer International Publishing. https://doi.org/10.1007/978-3-319-46709-2_7

Restrepo-Osorio, D. L. (2015). *DEFINING PERCEPTIONS OF WATERSHED MANAGEMENT IN A GREAT PLAINS AND IN AN ANDEAN WATERSHED*.

Restrepo-Osorio, D. L., & Brown, J. C. (2018). A Q methodology application on disaster perceptions for adaptation and resiliency in an Andean watershed symposium: Water and climate in Latin America. *Journal of Environmental Studies and Sciences*, *8*, 452–468.

Rogger, M., Agnoletti, M., Alaoui, A., Bathurst, J. C., Bodner, G., Borga, M., Chaplot, V., Gallart, F., Glatzel, G., Hall, J., Holden, J., Holko, L., Horn, R., Kiss, A., Kohnová, S., Leitinger, G., Lennartz, B., Parajka, J., Perdigão, R., … Blöschl, G. (2017). Land use change impacts on floods at the catchment scale: Challenges and opportunities for future research. *Water Resources Research*, *53*(7), 5209–5219. https://doi.org/10.1002/2017WR020723

Rosenberg, S., & Margerum, R. D. (2008). Landowner Motivations for Watershed Restoration: Lessons from Five Watersheds. *Journal of Environmental Planning and Management*, *51*(4), 477–496.

Saldaña, J. (2009). *The Coding Manual for Qualitative Researchers (3rd edition)* (3rd edition, Vol. 12). SAGE Publications.

Saarinen, T. F. (1966). Chapter V: Perception of the Range of Choice. *Department of Geography, University of Chicago*.

UWWRAPS. (2012). Upper Wakarusa Watershed Restoration and Protection Strategy 9 Element Watershed Plan. http://www.kswraps.org/files/attachments/upperwakarusa_plansummary.pdf

Van DIJK, A. I. J. M., Van NOORDWIJK, M., CALDER, I. R., BRUIJNZEEL, S. L. A., SCHELLEKENS, J., & CHAPPELL, N. A. (2009). Forest–flood relation still tenuous – comment on 'Global evidence that deforestation amplifies flood risk and severity in the developing world' by C. J. A. Bradshaw, N.S. Sodi, K. S.-H. Peh and B.W. Brook. Global Change Biology, 15(1), 110–115. https://doi.org/10.1111/j.1365-2486.2008.01708.x

Visión y Mision. (n.d.). Alianza Del Pastizal Para Conservar La Biodiversidad. http://www.alianzadelpastizal.org/institucional/mision-2/

Wilcox, Bradford. P., Huang, Y., & Walker, J. W. (2008). Long-term trends in streamflow from semiarid rangelands: Uncovering drivers of change. *Global Change Biology*, *14*, 1676–1689.

Chapter 4: Water Use Efficiency and Land Cover Variability on a Native Grassland Ranch on the Pampa Biome of Uruguay

INTRODUCTION

Ranchers in the Colonia Juan Gutiérrez face significant seasonal challenges with water management for livestock watering due to the drought events of summer and flooding events of winter. These situations are predicted to worsen due to the negative effects that expanding forestry plantations in the headwaters of the Queguay Grande river tributaries will have on the water cycle of the watershed (chapter 3). In this chapter we use a water use efficiency (WUE) approach to analyze the effects that forestry plantations may already have on the vegetation types of the Colonia properties and surrounding areas. Our objective is to provide this information as a way to urge conservation organizations, like the Alianza del Pastizal, to expand education, information, and support to ranchers in their efforts to address climate change adaptation, resilience, and mitigation.

Alianza del Pastizal is a non-profit conservation organization that works to preserve the temperate grasslands of the Southern Cone of South America by promoting conservation practices among ranching communities in Uruguay, Paraguay, Argentina, and Brazil. Although woody encroachment is mentioned in the organization's educational material, it does not appear to currently be a priority, however, given that it could jeopardize Alianza's efforts in the Colonia properties it should be considered in future efforts. Non-native invasive species from the surrounding forestry plantations, namely pines and eucalyptus, have the potential to spread intentionally or unintentionally to Colonia properties. Timely planning for woody encroachment management should allow ranchers in the Colonia to apply for available financial incentives or subsidies. This financial support could help in the installation of the infrastructure needed for targeted grazing of woody encroachment, and this financial support is also needed for the implementation of other adaptive practices like artificial watering distribution systems for livestock (chapter 3). As woody ecosystems are expected to thrive with climate change it is with great need that local and national funding organizations should prioritize projects that call for the implementation of practices that will aid in safeguarding the temperate grassland landscape and the ranching tradition of Uruguay (chapter 3).

We used WUE as a proxy for land cover change and we assumed that the conservation practices used to manage the properties would result in vegetation types that would more closely resemble the undisturbed conditions of the conservation area, rather than the highly disturbed vegetation types of the forestry plantations. For the purpose of this study, the conservation area WUE and GPP values were used as benchmarks to determine if there is evidence of woody encroachment in the Colonia properties. WUE and GPP values that resemble the forestry plantations may mean that woody vegetative species are already present in the Colonia properties; if this is the case, proactive measures might help mitigate the effects of woody encroachment. Therefore, in this chapter we carry out an exploration of WUE and GPP values using the TEAMS model to determine: 1) if woody encroachment and the forestry plantations are having effects on the vegetation types in the properties, and 2) if forestry plantations may be having effects on the water dynamics of the three sites analyzed(the Colonia properties, the conservation area, and the forestry plantations).

LITERATURE REVIEW

Water use efficiency (WUE) is defined as the ratio of carbon assimilated for gross primary production (GPP) to water loss from the system through seasonal or annual evapotranspiration (ET) (de Oliveira et al., 2018; Tang et al., 2014). We used the equation proposed in Beer et al. (2009); WUE=GPP/ET. Above ground GPP is the gross primary productivity in g cm^{-2} and ET is the evapotranspiration in kg H_2O (Beer et al., 2009; Oliveira et al., 2018). According to Brunsell et al. (2014) this equation is commonly used to explore relationships between the water cycle and terrestrial carbon (Brunsell et al., 2014; de Oliveira et al., 2018). Evaporation, which is dependent on solar radiation, can be separated into three elements: 1) water that infiltrates into the soil, then is absorbed by plants and transpired to the atmosphere, 2) water intercepted by foliage which then evaporates into the air, and 3) water which is intercepted by litter on the soil surface, then infiltrates into the litter, then into the soil, and then evaporates (de Oliveira et al., 2017; Wilcox et al., 2017). Transpiration is the main factor of evapotranspiration over land and it is connected to vegetative productivity (Monteith, 1988; Nosetto et al., 2011*)*. GPP is directly proportional to carbon assimilation (Beer et al., 2009).

WUE values change with annual seasonal variability typically displaying higher values during the wet seasons and lower values during the dry season, dependent on ET patterns (de Oliveira et al., 2017). Given that GPP is directly proportional to WUE, it also follows seasonal precipitation patterns. A study carried out in the Amazonia of Brazil indicated that during the low water availability and high ET of the dry season, GPP decreased due to increased stomatal closure and therefore decreased photosynthetic rates (de Oliveira et al., 2017). In a different study, Bathurst (2018) found that during the winter season, watersheds become saturated, there is little infiltration, and evapotranspiration is low (Bathurst et al., 2018), therefore biomass production and WUE decreases.

At large scales, groundwater aquifers and vegetative composition, especially in the riparian zones, regulate water supply and demand fluxes in the watershed (Wilcox et al., 2017).

Therefore, land use and land cover changes affect water quality and quantity, and the water balance in a watershed (Nosetto et al., 2011; de Oliveira et al., 2017). Land cover changes from grasslands to managed forests or forestry plantations have significant effects on WUE, GPP and ET. Oliveira et al. (2017) concluded that forested areas have WUE values ~67% higher than that of non-forested areas, including pastures (de Oliveira et al., 2017). These changes are attributed to the variation in vegetation species composition and structures which impact the leaf level WUE, which is in turn translated to larger ecosystem scale WUE changes (de Oliveira et al., 2017). Additionally, growth and senescence variation in vegetation types respond differently to seasonal dynamics (Brunsell et al., 2014; de Oliveira et al., 2017). GPP in areas that have been converted from grasslands to managed forests are higher because forest ecosystems produce more biomass than herbaceous ecosystems (Dang et al., 2014; El-Masri et al., 2013). At the same time, forested ecosystems present a higher ET regardless of native or non-native species composition compared to grasses due to longer roots that reach water deeper in the soil profile, and lower albedo than grassland ecosystems (Chescheir et al., 2008; Jackson et al., 2008; Nosetto et al., 2011; Zhang et al., 2001).

Land cover changes from grasslands to forestry plantations are believed to have the most profound changes in water balance in the watershed depending on the regimes set for managed forests (Farley et al., 2005; Nosetto et al., 2011; chapter 3). The establishment of trees has the capability of transforming soil porosity because of the growth of longer and larger roots which can reach into deep water in the soil profile compared to some herbaceous vegetation roots (Canadell et al., 1996; Chescheir et al., 2008; Nosetto et al., 2011). This leads to increased ET and lower water yield due to a reduction in storm flows, peak flow rates, and delayed peak outflows (Chescheir et al., 2008; Nosetto et al., 2011). This phenomenon potentially decreases flooding downstream (Chescheir et al., 2008), however, this is reversed when trees are harvested (chapter 3). In areas of afforestation with evergreen pine species, it is presumed that since they use water yearound (Scanlon et al., 2005), they might decrease water availability for stream baseflow or the recharge of groundwater aquifers (Farley et al., 2005; Nosetto et al., 2005; Nosetto et al., 2011).

STUDY AREA

Uruguay is part of the southern cone of South America and is located on the southeastern coast of the continent between the latitudes 30° and 35° South. Topographic features include rolling hills with elevations up to 550m and grassland/savanna biomes (Figure 1) (Chescheir et al., 2008). According to the Koppen classification system Uruguay displays a mid-latitude humid subtropical to temperate climate (Cfa) with hot and humid summers with thunderstorms, and a mild winter with precipitation events (Cheschier et al., 2008). Uruguayan temperatures increase from the southeastern coast of the country to the northwestern departments (Figure 3). According to 1961-1990 records from the Uruguayan Meteorological Institute, the thirty-year normal temperature for the country is 17.5°C (63.5°F) with an average maximum temperature of 19°C (66.2°F) over the Artigas department (See Figure 2 for location of departments), and an average minimum temperature of 16°C (60.8°F) over the Atlantic coast of the Rocha department (INUMET, n.d.-a). Precipitation in Uruguay takes the form of rain, with occasional hail or snow, and it tends to increase from southwest to the northeastern coast of the country (Figure 3). Annual average precipitation ranges from approximately 1100mm (43.3in) in the southwestern departments to approximately 1600mm (63in) in the Rivera department (Figure 3) (INUMET, n.d.-a, https://www.inumet.gub.uy/).

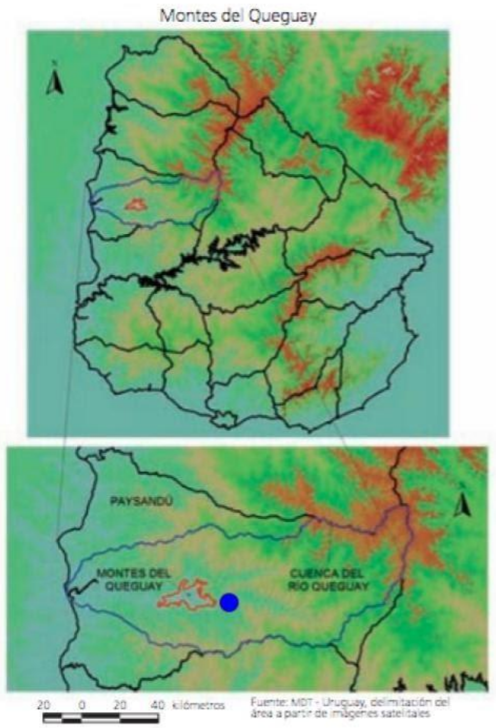


Figure 1. Orography and departments of Uruguay(top). Location of the Queguay Grande river watershed outlined in blue(bottom). Blue circle: study site. (Grupo Creativos de Guichón et al., 2012)

Figure 2. Departments of Uruguay. Red star: location of Montevideo, the capital of the country. Blue circle: study site. mapasinteractivos.didactalia.net

The center of the Paysandú department is approximately located in the -32.34° latitude and -58.0° longitude in the northwestern area of Uruguay (Figure 1, Figure 3). According to records from 1961-1990, Paysandú's 30-year normal annual temperature is 17.9°C (64.2°F), with an annual maximum temperature of 42.4°C (108.3°F) and an annual minimum temperature of -4.5°C (23.9°F). Additional records from 1901-2016 indicate an average monthly maximum temperature of 24.75°C (76.4°F) and an average monthly minimum temperature of 11.59°C (52.9°F). Paysandú's average annual temperatures closely follow those at the national level

(Figure 4). According to INUMET records from 1961 to 1990, the annual average precipitation in Paysandú during those years was 1218mm (48in) with a maximum 147mm (5.8in) in the month of March and a minimum of 70mm (2.7in) in the month of June (INUMET, n.d.-a). Precipitation patterns in Colonia Juan Gutiérrez from 1901 to 2016[6] follow the general national seasonal trend but deviate in magnitude. Records show a maximum of 125.32mm (5in) in April and a minimum of 82.48mm (3.2in) in July (Figure 5). The department of Paysandú is rich in streams and rivers and the majority of which serve as tributaries to the Queguay Grande river that runs from east to west of the department. The Queguay Grande river watershed occupies a significant portion of the department of Paysandú (Figure 1) and it runs through the Rincon de Perez conservation area and several forestry plantations before reaching the Uruguay River (chapter 2)

[6] https://climateknowledgeportal.worldbank.org/watershed/265/climate-data-historical

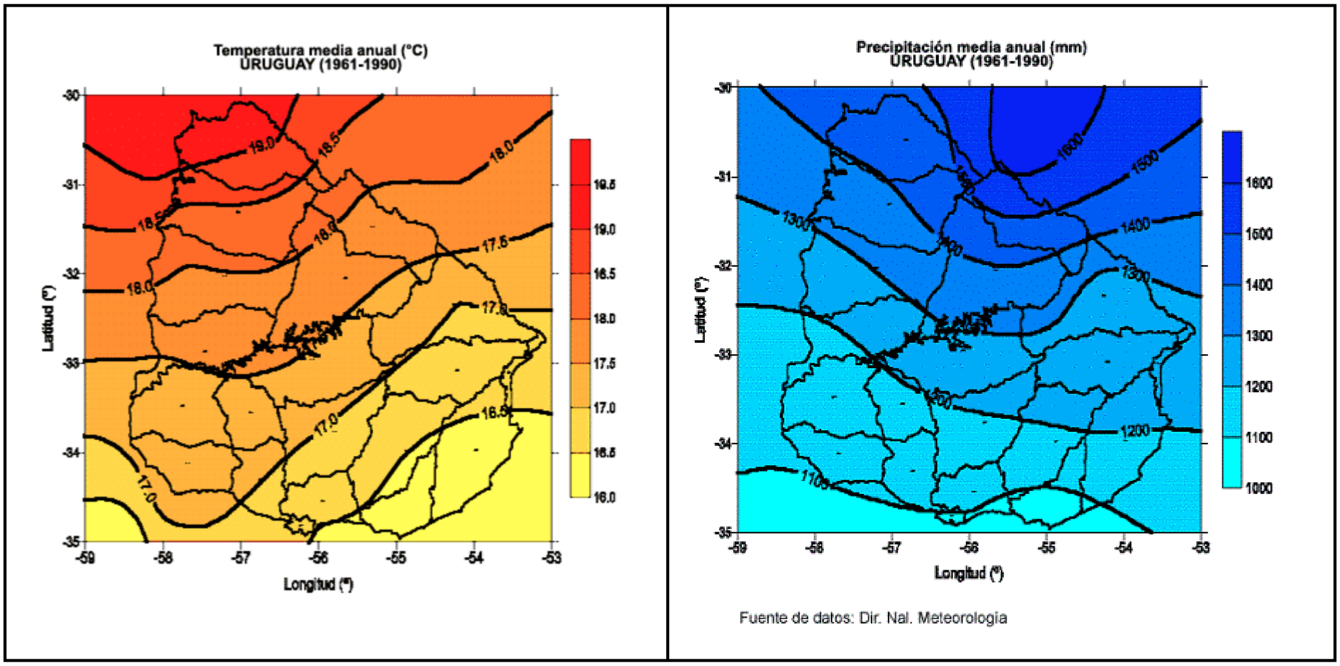


Figure 3. Uruguayan National annual average temperature in celsius from 1961-1990 (left) and national annual average precipitation in mililiters from 1961-1990 (right) (INUMET).

Uruguay has two high precipitation periods during the year. The period of precipitation with most rainfall occurs during the fall, and another period with lower rainfall occurs during the spring. The first period reaches its peak in April, which is halfway through fall, and the second period reaches its peak in October, which is halfway through spring (Figure 5). Precipitation in the Colonia Juan Gutiérrez follows this pattern; however, the precipitation events present a larger magnitude than the national monthly mean average (Figure 5). Temperature in the Colonia closely follows the national temperature (Figure 4) deviating minimally in the summer when temperatures go up to 24.75°C (76.55°F). Winter temperatures in the Colonia do not seem to deviate much from national temperatures and go as low as 11.59°C (52.86°F) (Figure 4). Different vegetation types react differently to the seasonal variations in precipitation and temperature and therefore regulate the water cycle in different ways. This is of special interest to ranchers and other land managers in the Queguay Grande river watershed, given the history of seasonal flooding and drought that affect the ranching enterprise and the livelihood of ranching families.

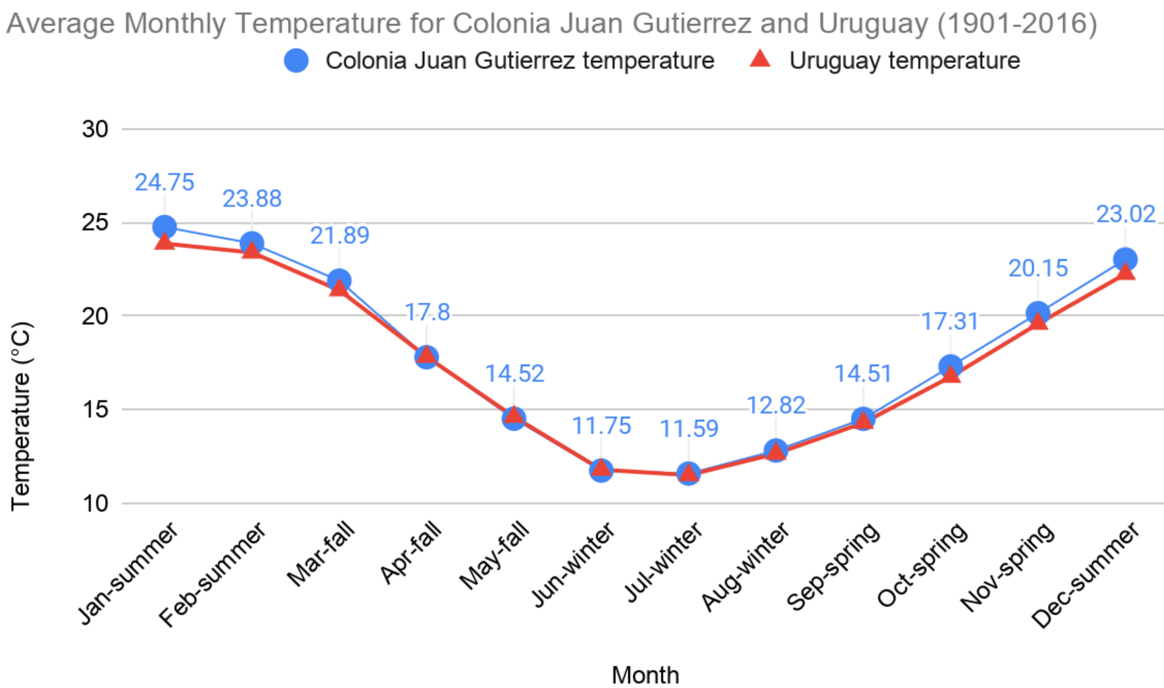


Figure 4. Average Monthly Temperature for the Colonia Juan Gutiérrez (blue line and blue circles) and for Uruguay (red line and red triangles) from 1901 to 2016.

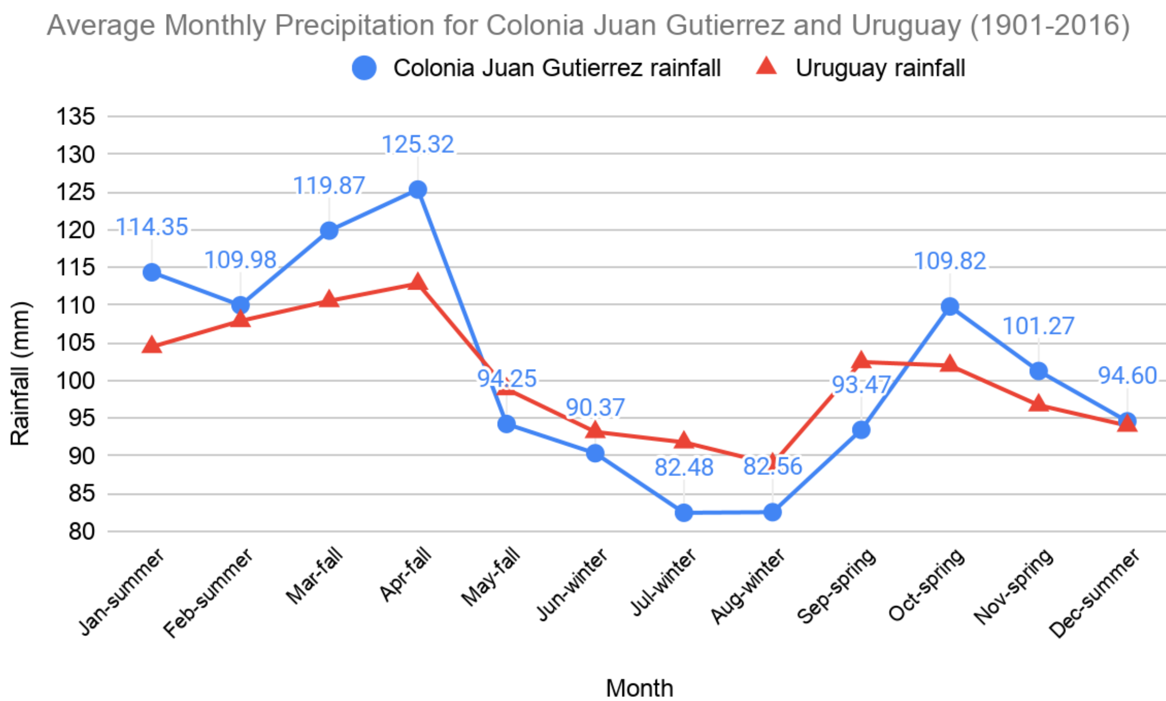


Figure 5. Average Monthly Precipitation for the Colonia Juan Gutiérrez (blue line and blue circles) and for Uruguay (red line and red triangles) from 1901 to 2016.

METHODS

Temporal Evapotranspiration Aggregation Method (TEAM) tool for water use efficiency (WUE), evapotranspiration (ET), and gross primary productivity (GPP).

TEAM is a Google Earth Engine tool developed in 2019 by Jim Coll in collaboration with Gabriel de Oliveira. Both coauthors assisted in the development of this project as it is the second application of the TEAM tool in an academic manuscript headed to publication, and the first time the tool will be used in the temperate grassland habitat of South America. Previous studies have validated MOD16A2 and MOD17A2H data sets using flux towers in the Brazilian Amazonia to compare WUE, GPP, and ET values in agricultural, primary and secondary tropical forests, and pastureland cover types (de Oliveira et al., 2017). The data presented an average error of ~11% for MODIS16A2 and ~13% for MODIS17A2H when compared to flux tower ground measurements. De Oliveira et al. (2017) found that MODIS presents higher accuracy for forest land cover compared to pasture land cover type (de Oliveira et al., 2017).

We used TEAM to assess the land cover composition and distribution surrounding the Colonia Juan Gutiérrez, and to obtain the WUE, ET, and GPP values. Water Use Efficiency is defined as the ratio of carbon assimilated as biomass production Gross Primary Productivity (GPP), to the units of water used by vegetation Evapotranspiration (ET). TEAM uses MOD16A2 and MOD17A2H (500 m pixel) data sets to carry out its functions (Coll, 2019). TEAM calculates WUE using MOD16A2 for an 8-day composite of GPP and an 8-day composite for ET using MOD17A2H from 2001-2018. For this purpose, the shapefiles of the property boundaries and paddock distribution were obtained from the president of the Sociedad de Fomento Rural de la Colonia Juan Gutiérrez (*Development Society of the Juan Gutiérrez Colony*). Jim Coll, the developer of the TEAM platform, imported these shapefiles into the TEAM platform and made them available as a *custom shapefile* under the *unit to aggregate* feature (Coll, 2019). The IGBP land cover classification MCD12Q1 database was selected in the *land cover* feature of the TEAM tool and the *custom shapefile* under the *unit to aggregate* feature was selected.

Colonia Juan Gutiérrez Properties

The zoom feature was used to frame the polygons outlining the properties in the Colonia Juan Gutiérrez. *WUE* was chosen as the *variable to view*, the *mean* was chosen for the *temporal stat to aggregate*, the *spatial stat to aggregate*, and the *table stat to aggregate*. The *year-to-view* was left as default, the *images to animate* were left as the default of 24, and the *timestep (ms)* was also left as the default 1000. Each one of the 145 polygons outlining the paddock distribution in the Colonia properties were selected. The WUE values for all vegetation types in the properties were displayed in time series and monthly aggregate graphs, both of which were exported as PNG and CSV files to record the WUE for all vegetation types in the ranches. All CSV files were compiled on Google Sheets to obtain a monthly mean WUE, GPP and ET value and create graphs of the WUE of each vegetation type in the Colonia properties. The GPP and ET for the properties were calculated by choosing either variable in the *variable to view* option in the TEAM platform. The entirety of the steps just outlined for the calculation of the WUE variable were replicated to obtain the GPP values and again to obtain the ET values.

Rincon de Perez Conservation Area and Forestry Plantations

The *Map Bounding Box (on click)* option was chosen as the *unit to aggregate over*, *WUE* was chosen as the *variable to view*, and as recommended by the coauthors of this project, the *mean* was the *temporal stat to aggregate*, the *mean* was also chosen as the *spatial stat to aggregate*, and the *mean* was also chosen as the *table stat to aggregate*. The *year-to-view* was left as default, the *images to animate* were left as the default of 24, and the *timestep (ms)* was also left as the default 1000. The satellite viewing option was chosen initially to locate the area of interest. The conservation area has a more defined outline compared to the extensive forestry plantations (chapter 3). The forestry plantation area chosen was located south west of the conservation area where these plantations seem to be well established and have a high density of trees. Once these areas were located, they were enlarged using the zoom feature in the TEAM tool until the eastern and westernmost outlining borders of the area were framed on the screen.

The center of the area was visually estimated and selected with a click in order to activate the *map bounding box.* The WUE values for all vegetation types are displayed in a time series and monthly aggregate graphs, both of which were exported as PNG and CSV files to record the

WUE for each vegetation type at each zoom level. The first zoom level covers approximately 22km^2. We framed the first zoom level *map bounding box* on the screen, which appears ghosted, and zoomed in again. We chose different bounding boxes to ensure that we obtained the different vegetation types per study site in addition to the corresponding WUE values for all vegetation types in each site. Then we clicked the center of the area to create a new *map bounding box* on the second zoom level, which covers approximately 12km^2. The same procedure was repeated for the third zoom level, which covers approximately 6km^2. CSV files were compiled to obtain a monthly mean WUE, GPP, and ET values and create graphs of the WUE of each vegetation type in the conservation area and in the forestry plantations. The GPP and ET for the conservation area and the forestry plantations were calculated by choosing either variable in the *variable to view* option in the TEAM platform and repeating the same steps outlined for the calculation of the WUE variable.

RESULTS

Water use efficiency of vegetation types in Colonia Juan Gutiérrez properties

The WUE analysis of the vegetation types on the properties of the floodplain of the Queguay Grande river and the properties of the floodplain of the Queguay Chico river, both part of the Colonia Juan Gutiérrez, show that most values follow a similar pattern. WUE seems to increase from January to March where it steeply increases and decreases in July after which it increases again and then slowly decreases from October until the end of the year (Figure 6). The evergreen broadleaf forest WUE is higher than the rest of the vegetation types with a WUE of 2.37 g C Kg^{-1} H_2O, whereas woody savannas in the properties had the lowest WUE value of 1.14g C Kg^{-1} H_2O. Evergreen broadleaf forests and grasses had the highest monthly mean WUE of

1.92g C Kg^{-1} H_2O, and woody savannas and savannas had the lowest monthly mean WUE of 1.76g C Kg^{-1} H_2O (Table 1).

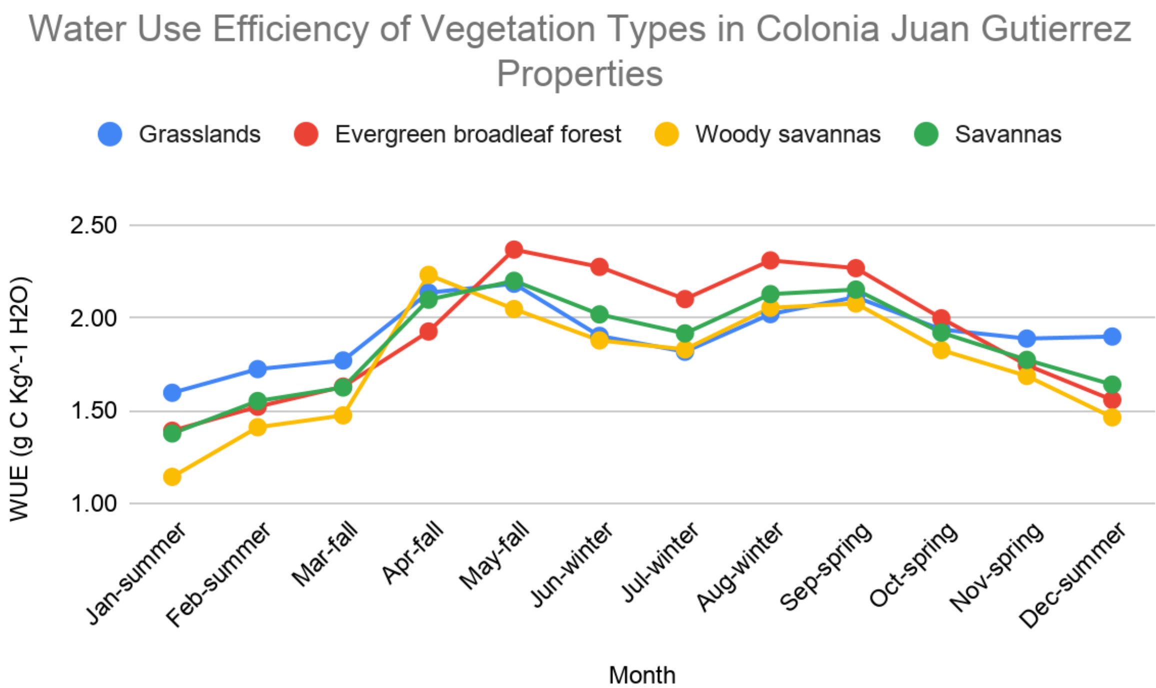


Figure 6. TEAM tool WUE aggregated values for vegetation types in Colonia Juan Gutiérrez properties from 2001-2018

COLONIA JUAN GUTIÉRREZ PROPERTIES			
Vegetation Type	**WUE (g C Kg^{-1} H_2O)**		**Monthly mean WUE**
	Min	**Max**	
Woody savannas	1.14	2.23	1.76
Savannas	1.38	2.20	1.76
Evergreen broadleaf forest	1.39	2.37	1.92
Grasses	1.60	2.18	1.92

Table 1. WUE mean of minimum values and mean of maximum values for the vegetation types in the Colonia Juan Gutiérrez properties, and overall monthly mean WUE per vegetation type.

Water use efficiency of vegetation types in the Rincon de Perez conservation area

The WUE analysis of the vegetation types in the Rincon de Perez conservation area show all vegetation types following a similar pattern to that evidenced in the properties of the Colonia Juan Gutiérrez, where WUE increases from January to March, decreases in July, increases again and slowly decreases from October until the end of the year (Figure 7). The evergreen broadleaf forests and deciduous broadleaf forests follow a similar pattern, but with higher WUE values than the rest of the vegetation types in this site. Grasslands, woody savannas, and savannas follow a similar pattern, but they display lower WUE values than the evergreen and deciduous broadleaf forests. Mixed forests follow this pattern as well, but with WUE values between the forest vegetation types, and grasslands, savannas and woody savannas (Figure 7).

The evergreen broadleaf forest WUE is higher than the rest of the vegetation types, with a WUE of 3.08 g C Kg^{-1} H_2O, and the deciduous broadleaf forest WUE followed closely, with a WUE value of 2.95g C Kg^{-1} H_2O (Table 2). The lowest WUE value of 1.04g C Kg^{-1} H_2O corresponded to deciduous broadleaf forest species. The evergreen broadleaf forest WUE values were similar, with a minimum WUE of 1.14g C Kg^{-1} H_2O. Evergreen broadleaf forests and grasses had the highest monthly mean WUE of 2.22g C Kg^{-1} H_2O, and woody savannas and savannas had the lowest monthly mean WUE of 1.65g C Kg^{-1} H_2O (Table 2).

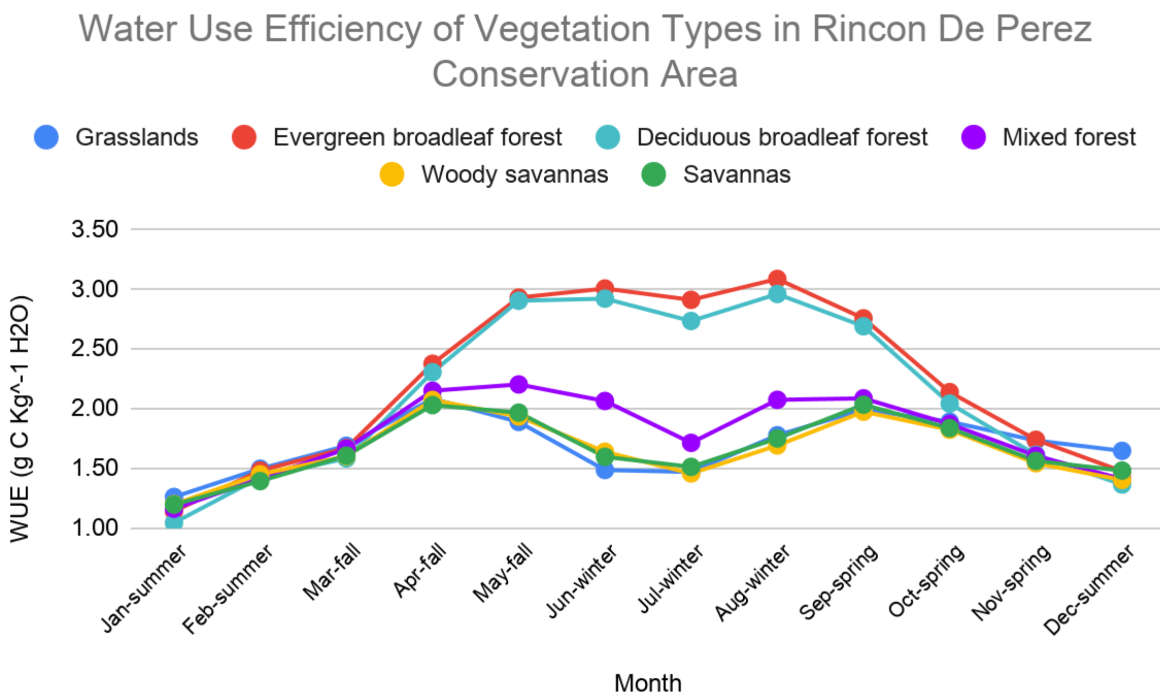


Figure 7. TEAM tool WUE aggregated values for vegetation types in Rincon de Perez conservation area from 2001-2018

RINCON DE PEREZ CONSERVATION AREA			
Vegetation Type	**WUE (g C Kg^{-1} H_2O)**		**Monthly mean WUE**
	Min	**Max**	
Deciduous Broadleaf forest	1.04	2.95	2.13
Evergreen broadleaf forest	1.14	3.08	2.22
Mixed forest	1.16	2.20	1.78
Savannas	1.20	2.03	1.66
Woody savannas	1.20	2.07	1.65
Grasses	1.26	2.08	1.70

Table 2. WUE mean of minimum values, and mean of maximum values for the vegetation types in the Rincon de Perez Conservation area, and overall monthly mean WUE per vegetation type.

Water use efficiency of vegetation types in the forestry plantations

The Water Use Efficiency analysis of the vegetation types in the forestry plantations show no clear pattern (Figure 8). Grasses had the highest WUE value of 2.20g C Kg^{-1} H_2O and closed shrublands had the lowest WUE value of 1.11g C Kg^{-1} H_2O. Grasses had the highest monthly mean WUE of 1.95g C Kg^{-1} H_2O, and mixed forests had the lowest monthly mean WUE of 1.46g C Kg^{-1} H_2O (Table 3).

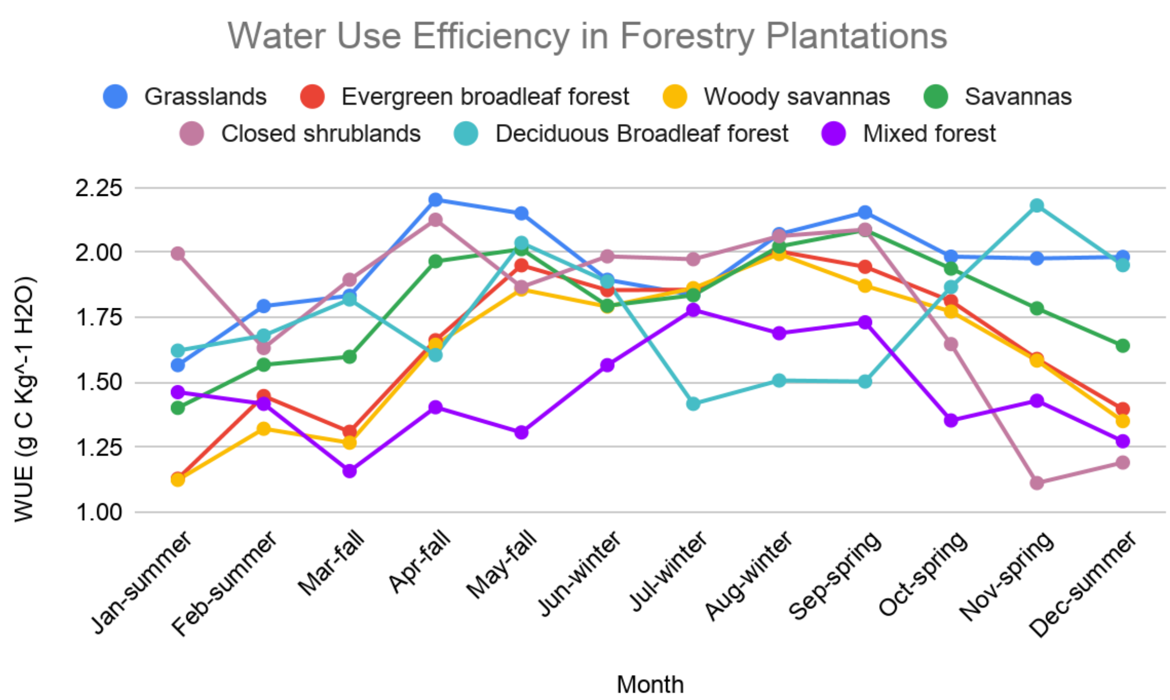


Figure 8. TEAM tool WUE aggregated values for vegetation types in the forestry plantations from 2001-2018.

FORESTRY PLANTATIONS			
Vegetation Type	**WUE (g C Kg^{-1} H_2O)**		**Monthly mean WUE**
	Min	**Max**	
Closed shrublands	1.11	2.13	1.80
Woody savannas	1.12	1.99	1.62
Evergreen broadleaf forest	1.13	2.00	1.66
Mixed forest	1.16	1.78	1.46
Savannas	1.40	2.09	1.80
Deciduous broadleaf forest	1.42	2.18	1.76
Grasses	1.57	2.20	1.95

Table 3. WUE mean of minimum values, and mean of maximum values for the vegetation types in the forestry plantations, and overall monthly mean WUE per vegetation type.

Gross Primary Productivity for selected vegetation types in all sites

Gross Primary Productivity values separate into two groups, with vegetative species from the forestry plantations and vegetative species from the properties following one pattern, and the vegetative species from the conservation area following a different pattern (Figure 9). The vegetation types in the properties follow a similar pattern as that of the forestry vegetative species but with lower GPP values. GPP values of the evergreen broadleaf forest species, deciduous broadleaf forest species, and woody savanna species from the conservation area seem to decrease to a peak in March, slightly increase and slowly decrease until September, where the pattern starts increasing again until the end of the year. On the other hand, GPP values for the evergreen broadleaf forest species and the woody savannas in the forestry plantations, and the GPP values for the woody savannas and the savannas in the properties, seem to increase to a peak in February, then decrease until approximately July, increase to November and then decrease until the end of the year (Figure 9).

The minimum GPP is attributed to both the woody savannas in the properties and the woody savannas in the conservation area, with a value of 0.011g C m^{-2} (Table 4). The maximum GPP is attributed to the evergreen broadleaf forests in the conservation area, with a value of 0.072g C m^{-2}. The evergreen broadleaf forests in the conservation area had the highest monthly mean GPP value of 0.047g C m^{-2}, whereas the savannas in the properties had the lowest GPP value of 0.028g C m^{-2} (Table 4).

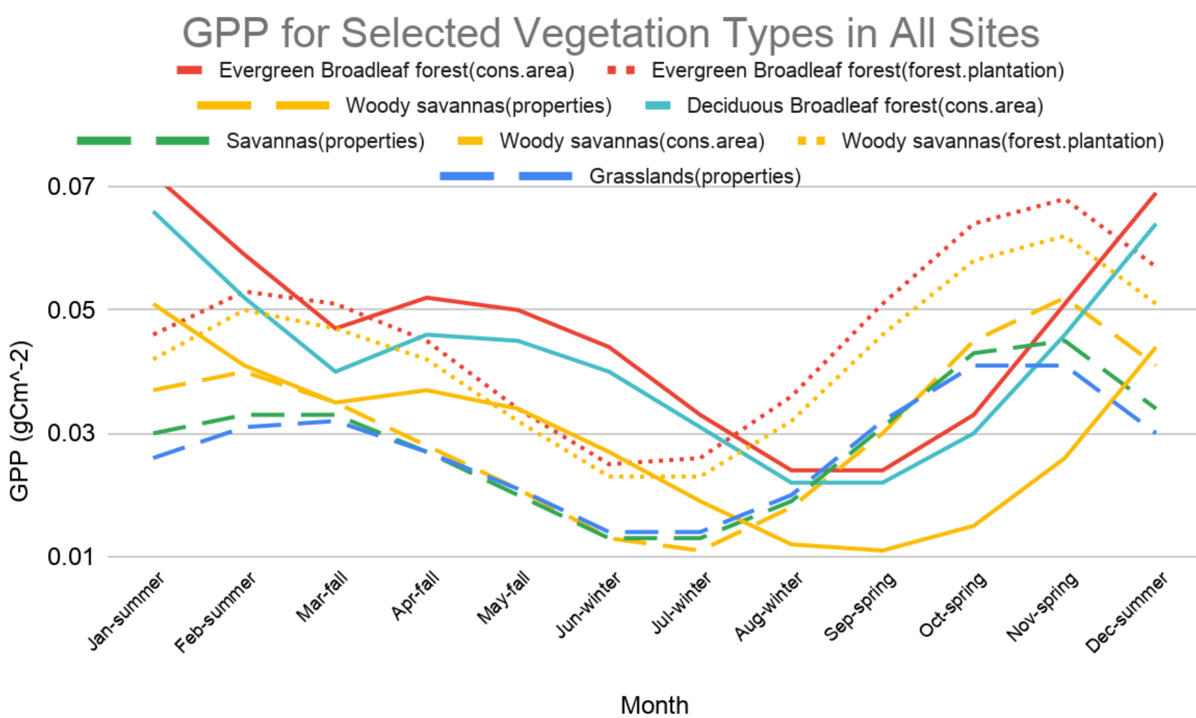


Figure 9. TEAM tool GPP aggregated values for selected vegetation types in all sites from 2001-2018

Vegetation Type	GPP (g C m^{-2})		Monthly mean GPP
	Min	Max	
Woody savannas(properties)	0.011	0.052	0.031
Savannas (properties)	0.013	0.045	0.028
Grasses (properties)	0.014	0.041	0.027
Woody Savannas (forestry plantations)	0.023	0.062	0.042
Evergreen broadleaf forest (forestry plantations)	0.025	0.068	0.046
Evergreen broadleaf forest (conservation area)	0.024	0.072	0.047
Woody Savannas (conservation area)	0.011	0.051	0.029

Table 4. GPP mean of minimum values and mean of maximum values for the vegetation types across three study sites: Colonia Juan Gutiérrez properties, Rincon de Perez conservation area, and forestry plantations, and overall monthly mean GPP per selected vegetation type.

Evapotranspiration for selected vegetation types in all sites

Evapotranspiration values for the selected vegetation types in all sites follow a similar pattern (Figure 10). This pattern shows a decrease from January to a peak in March, then a decrease until the months of June and July, an increase until a peak in November and a slight decrease until the end of the year. Vegetation types in the forestry plantations have higher ET values than the rest of the vegetation types in the other sites from March to October. Then, vegetative species in the properties seem to have the second highest ET but are similar to the rest of the vegetation types from all sites at the bottom of the curve from May to August. The lowest ET values are associated with vegetative types from the forest plantation site, but are similar to the rest of the vegetation types from all sites during the months of May to August (Figure 10).

Woody savannas in the conservation area had the lowest ET values of 7.51mm, while the evergreen broadleaf forest species in the conservation area had the lowest ET value of 42.68mm

(Table 5). The savannas located in the properties had the lowest monthly mean ET value of 16.50mm, and the evergreen broadleaf forest in the forestry plantations had the highest monthly mean ET value of 28.12mm (Table 5).

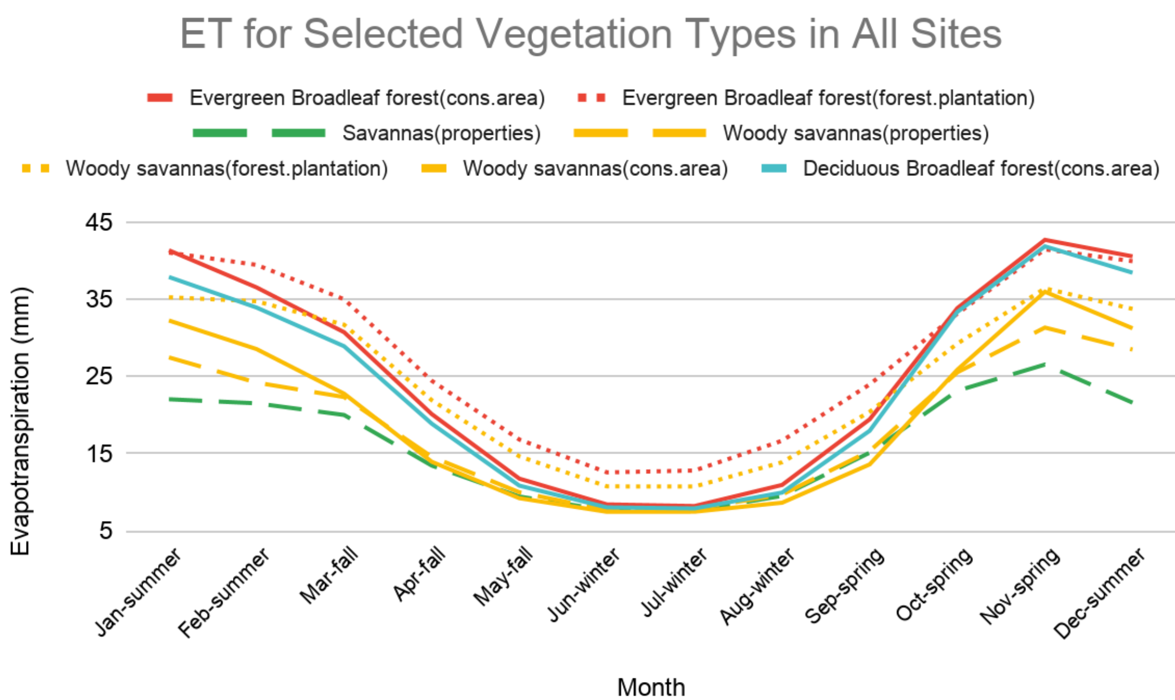


Figure 10. TEAM tool ET aggregated values for selected vegetation types in all sites from 2001-2018

Vegetation Type	ET (mm)		Mean monthly ET
	Min	Max	
Woody savannas(properties)	7.72	31.34	18.74
Savannas (properties)	7.68	26.55	16.50
Woody Savannas (forestry plantations)	10.78	36.41	24.48
Evergreen broadleaf forest (forestry plantations)	12.61	41.45	28.12
Evergreen broadleaf forest (conservation area)	8.25	42.68	25.40
Woody Savannas (conservation area)	7.51	35.97	19.78
Deciduous broadleaf forest (conservation area)	7.95	41.84	24.02

Table 5. ET mean of minimum values, and mean of maximum values for the vegetation types across three study sites: Colonia Juan Gutiérrez properties, Rincon de Perez conservation area, and forestry plantations, and overall monthly mean ET per selected vegetation type.

DISCUSSION

This study provides insights about the potential effects that forestry plantations and woody encroachment are having on the different vegetation types in the Colonia Juan Gutiérrez properties, in addition to impacts on water fluxes in the properties, conservation area, and forestry plantations. The WUE analysis demonstrated that the vegetation in the forestry plantation seems to encounter periods of instability where biomass production and water processes are disrupted. These periods are most likely associated with the harvesting periods in the forestry plantations, which have been shown to affect the water fluxes in the watershed (See Figure 2, chapter 2 for evidence of forestry harvesting (1995-2016); chapter 3). The GPP analysis suggests a potential effect that the forestry plantations are having on the vegetation types in the properties. Although all vegetative types from all sites follow a similar pattern in GPP, it is clear that the vegetative types in the properties are following GPP values from the forestry plantations more closely than GPP values from the conservation area. This is of special interest given the conservation efforts by several local and national conservation organizations, including the Alianza del Pastizal. Land conversion of temperate grasslands to forests would jeopardize the livelihood of the ranching communities in the Colonia Juan Gutiérrez, located in the floodplain of the Queguay Grande and the Queguay Chico rivers.

The WUE analysis goes hand in hand with the land cover type distribution analysis carried out in chapter 2 of this dissertation, where we learned that the composition of the forestry plantations consists of deciduous broadleaf forests and mixed forests on the outermost borders, then closed shrublands as we approach the core, and lastly grasses and evergreen broadleaf forests at the core of these forestry plantations. At the same time, the Rincon de Perez conservation area is composed of deciduous broadleaf forests in the outermost border, then mixed forests as we approach the core, and evergreen broadleaf forests at the core of the conservation area. In general, the properties in the Colonia Juan Gutiérrez displayed grasslands in the outer areas, then savannas as we approach the riparian area, and lastly, woody savannas and evergreen broadleaf forests at the core of the riparian area (Table 6). This land cover vegetative distribution will be reflected in the patterns of WUE evidenced in this chapter.

	Zoom Level 1 Outermost area	**Zoom Level 2**	**Zoom Level 3 Innermost area**
Forestry Plantations	-Deciduous broadleaf forests -Mixed forests	Closed shrublands	-Grasslands -Evergreen broadleaf forests -Woody savannas -Savannas
Rincon de Perez Conservation Area	Deciduous broadleaf forests	Mixed forests	Evergreen broadleaf forests
Properties in the Colonia Juan Gutiérrez	Grasslands	Savannas	-Woody savannas -Evergreen broadleaf forests

Table 6. Land cover type distribution in the forestry plantations, the Rincon de Perez conservation area, and the properties in the Colonia Juan Gutiérrez. Analysis completed using the *map bounding box* and the *zoom* feature of the Google Earth Engine TEAM tool.

Water use efficiency of vegetation types in Colonia Juan Gutiérrez properties

Evergreen forest species maintain their leaves during the winter; therefore, water flux processes can still occur with little disruption compared to deciduous species that become dormant during the winter. The production of biomass by evergreen species, or GPP, is ongoing, therefore it results in higher WUE values compared to other vegetation types in the properties. Given that the relationship between GPP and WUE is directly proportional, a high GPP is often reflected in a high WUE. Given that the evergreen broadleaf forest species in the properties remain active during the winter using water for biomass production, they could influence water cycle dynamics in the watershed during that season.

Water use efficiency of vegetation types in the Rincon de Perez conservation area

The WUE analysis of the conservation area presented the patterns found among grasslands, evergreen broadleaf forests, deciduous broadleaf forests, mixed forests, savannas, and woody savannas of this site. All vegetation type WUEs sharply increase from March to November. At the same time, all vegetation types seem to be affected by the winter low rainfall and low temperatures, a phenomenon that is displayed as a decrease in the WUE annual pattern in the month of July. Naturally, the evergreen broadleaf forest and the deciduous broadleaf forest species showed a high WUE, followed by the mixed forest WUE. This is due to the biomass produced by these vegetation types and the canopy cover they provide, which is greater than 60% according to the IGBP land cover description system used for this study (chapter 2). The lowest WUE was displayed by the savannas, woody savannas, and grasses in the conservation area, which may indicate the presence of shading and competition for water by trees. Photosynthetic processes are reduced by the lack of light, and diminished water access affects the biomass production, or GPP, of these vegetation types. Therefore, a decrease in GPP translates into a decrease in WUE values. Evidently, evergreen broadleaf forest vegetative species remain more active than the rest of the vegetative types in the conservation area during the winter, actively using water from the watershed and influencing the water cycle dynamics in the watershed during that season.

Water use efficiency of vegetation types in the forestry plantations

Vegetation types in the forestry plantations display WUE values with no clear pattern. The evergreen broadleaf forests and the woody savannas WUE somewhat follow the seasonal WUE patterns of the vegetation types in the conservation area and in the properties of the Colonia. This pattern might indicate a more stable state during the growing trajectory of forestry species like pine and eucalyptus compared to the rest of the vegetation types in this site. WUE values for deciduous broadleaf forest and mixed forest do not present clear patterns. However, the decrease of deciduous broadleaf forest WUE during the winter may indicate the loss of leaves and a state of dormancy. WUE values for grasslands, closed shrublands, and savannas in the forestry plantations do not seem to decrease during the year nor fluctuate seasonally. WUE values in the forestry plantations are within the range WUE values for vegetation types in the other sites, however, there are no seasonal patterns evident in the readings. These readings may reflect the major disruptions that take place in forestry plantations during harvesting, as the other vegetative types adjust to changes in canopy cover like water availability, and sunlight availability. WUE values for grasses seem to remain high throughout the sampling years, which may hint at an increased access to rainfall and sunlight during harvesting periods, or it may indicate managed forests with a density that favors grass growth and potential silviculturist activities.

Gross Primary Productivity for selected vegetation types in all sites

The biomass production of vegetative species is directly proportional to WUE values, and therefore, GPP values are important indicators of what could be contributing to WUE variation. GPP values are expected to increase during spring and summer, corresponding to the months of October through February, when there is the highest rainfall and the highest temperature of the year, although there can be some variability in these dates. On the other hand, GPP values are expected to decrease during the winter, approximately March through September, when rainfall and temperatures decrease. GPP values were measured for all vegetation types in all sites. These GPP values seem to separate into two groups, vegetation types in the conservation area, and vegetation types from the forestry plantations and the properties. Both groups seem to follow a similar pattern, however, the conservation area vegetation types seem to delay the response to seasonal change. This is especially evident when looking at the winter months of June, July, and August when there is a decrease in rainfall and temperature, resulting in a decrease in biomass production. Vegetation types from the forestry plantations and the properties have the lowest GPP values in the middle of winter, whereas vegetation types in the conservation area have the lowest GPP values during the end of winter and early spring.

The GPP values for each vegetation type correspond to the canopy coverage it provides. The IGBP land cover classification system categorizes vegetation types according to the tree cover it presents. In increasing order, grasslands < savannas < woody savannas < evergreen broadleaf forests = deciduous broadleaf forests = mixed forests (chapter 2). Therefore, it is expected to have evergreen broadleaf species with the highest GPP values, followed by deciduous broadleaf forests GPP values, and woody savanna GPP values in the conservation area. In the same way, it is expected that GPP values for evergreen broadleaf forests will be higher than GPP values for woody savannas in the forestry plantations. Lastly, it is expected for woody savanna GPP values to be higher than GPP values for savannas, and GPP values for grasses to be the lowest. This GPP analysis, however, indicated that the vegetation types in the properties are following the patterns of the forestry plantations instead of the conservation area vegetation types. This may provide indications of potential woody vegetation encroachment similar to the species found in the forestry plantations, namely eucalyptus and pine (chapter 2). Most importantly, the vegetation types in the ranches in the Colonia Juan Gutiérrez may be indicating a deviation from conservation efforts and instead it may be transitioning to resemble the vegetation types in the forestry plantations.

Evapotranspiration for selected vegetation types in all sites

All vegetation types in all sites seem to follow the same annual evapotranspiration pattern. There is a decrease in ET values from early fall in March to early spring in September. Evergreen broadleaf forests and woody savannas in the forestry plantations have the highest ET values from early fall to early spring, followed by the conservation area vegetation types, while the vegetation types in the properties show the lowest ET values. Evapotranspiration processes are highly dependent on temperature; therefore ET patterns resemble those of the national and local temperature patterns (Figure 4). Vegetation types with high canopy cover have more surface area for evaporative opportunities, therefore the forestry plantations and the conservation area have a higher ET than vegetation types in the properties of the Colonia. Therefore, higher canopy vegetation like evergreens and deciduous forests have a higher contribution to watershed hydrological fluxes and the water cycle.

Temperate Grasslands Water Use Efficiency

The main focus of the Alianza del Pastizal is to promote conservation practices for the preservation of native temperate grasslands, its biodiversity, and the livelihoods that depend on this ecosystem in the southern cone of South America. The GPP analysis, however, indicates that the savannas, woody savannas, and the grasses in the Colonia Juan Gutiérrez properties resemble the GPP values of the vegetation types in the highly disturbed forestry plantations. This finding points at the influence that forestry plantations are having on surrounding vegetation types, including those in the properties. This study compared the WUE values of several vegetation types, including grasses, in forestry plantations, in the conservation areas, and in the properties of ranchers who associate with the Alianza. Our analysis indicates that the monthly mean WUE for grasses is higher in the forestry plantations compared to that of the properties and the conservation areas. The grasslands in the forestry area displayed a WUE value of 1.95 g C Kg^{-1} H_2O, grasses in the properties displayed a WUE value of 1.92 g C Kg^{-1} H_2O, and the grasses in the conservation area displayed a WUE value of 1.70 g C Kg^{-1} H_2O. Evidently, the WUE values for vegetation types in the Colonia Juan Gutiérrez properties is closer to the WUE values of the forestry plantations vegetation types than to the WUE values of the conservation area vegetation types. This is additional evidence of the effects that the forestry plantations may be having on vegetation types in the Colonia Juan Gutiérrez properties.

Compared to other WUE values for temperate grassland biomes around the world, the WUE values for the property grasses in the Colonia Juan Gutiérrez seem to be in the upper range. An analysis of global temperate grasslands suggests a mean monthly WUE value during the growing season within the range of .03 - 1.64 g C Kg^{-1} H_2O (Law et al., 2002). A study carried out in China from 2003 to 2005 in an area of temperate grasslands, which was fenced since 1979, found a grassland WUE value within the range of .80+-.44 g C Kg^{-1} H_2O (Hu et al., 2008). A later study in this same area found a WUE value of 1.74 g C Kg^{-1} H_2O for temperate grasslands (Zhu et al., 2014). In the USA, a study carried out from 1897 to 2007 found an average annual WUE value of .94 g C Kg^{-1} H_2O for temperate grasses in the southern region of the country (Tian et al., 2010). The results from this study indicate that WUE values for grasses in the Rincon de Perez conservation area, 1.70 g C Kg^{-1} H_2O, resembling the undisturbed temperate grasses in the studies reviewed, more than the grasses in the forestry plantations and the properties. WUE values for the grasses in the properties of the Colonia Juan Gutiérrez, 1.92 g C Kg^{-1} H_2O, were much closer to the WUE values of the grasses in the forestry plantations of 1.95 g C Kg^{-1} H_2O. This may serve as another indicator of where in the WUE spectrum the grasslands in the properties are situated and that it seems to be moving more towards values associated with grasses in the forestry plantations.

Connections

Ranchers in the Colonia Juan Gutiérrez face difficulties in providing water security for their livestock during extreme seasonal drought and flooding events. At the same time, this ranching community is under the threat of woody encroachment by invasive species derived from the forestry plantations. Previous studies have shown that changes in land cover from grasslands to managed forests has serious effects on the water dynamics in the watershed by increasing storm peaks and increasing floods after tree harvesting (chapter 3). All of these issues are exacerbated by climate change, which is predicted to increase the magnitude of thunderstorms, increase floods, and increase summer and winter temperatures (Chescheir et al., 2008). This chapter provided additional information, indicating the effects that expanding forestry plantations, and potential woody encroachment to the Colonia Juan Gutiérrez properties, have in the water use efficiency fluxes and biomass production of different vegetation types in the watershed. More precisely, this information supports the idea that the presence and expansion of forestry plantations are possibly already having effects on the properties of the Colonia Juan Gutiérrez by encroaching via the riparian area of the Queguay Grande river, and influencing the WUE and biomass production of the vegetative species there (chapter 2).

The potential effects that expanding forestry plantations are already having on the properties of the Colonia Juan Gutiérrez will increase over time with increasing climate variability. For this reason, it is imperative for conservation nonprofit organizations, like the Alianza del Pastizal, and associated local and national governmental organizations such as the Ranching, Agriculture, and Fishing Ministry of Uruguay (RAFMU), to collaborate and provide the necessary tools for ranchers to face upcoming challenges. Perceptions from the ranchers in the Colonia Juan Gutiérrez make it clear that they prefer woody encroachment management practices that align with their socioeconomic and cultural contexts. We identified targeted grazing as a practice that has already been implemented in ranches of the region, and which uses a lens of coexistence rather than eradication (chapter 2). At the same time, ranchers in the Colonia Juan Gutiérrez have attempted to build and maintain adaptive capacity to extreme seasonal changes that affect their water availability for livestock. However, ranchers' adaptation trajectories have been different due to the variation in available funds to install artificial waterer systems in their properties (chapter 3). The Uruguayan government has recognized rancher's needs and made subsidies and financial incentives available for the installation of artificial watering distribution systems. However, not all ranchers have been able to obtain this financial help and others need to expand or repair the artificial watering system they already have.

The preparation for the implementation of targeted grazing for woody encroachment management requires similar infrastructure to that needed for the installation of artificial watering distribution systems in rotational grazing operations (chapter 2 and 3). This initial step in implementation requires a large financial investment from ranchers, which is not always available, therefore financial incentives and subsidies are of great need in order to proactively prepare for upcoming changes. There should be a sense of urgency among extension agents from organizations like Alianza, RAFMU, AUGAP, and the Plan Agropecuario to provide education and information regarding the implementation of targeted grazing and the consequences that forestry plantations are having on the Queguay Grande river watershed. Education and financial support for the ranching community will empower them to potentially demand change regarding the forestry enterprise expansion and give ranches control over the ways that they can adapt, mitigate and become resilient to negative effects derived from climate change.

References

Bathurst, J., Birkinshaw, S., Johnson, H., Kenny, A., Napier, A., Raven, S., Robinson, J., & Stroud, R. (2018). Runoff, flood peaks and proportional response in a combined nested and paired forest plantation/peat grassland catchment. *Journal of Hydrology*, *564*, 916–927.

Beer, C., Ciais, P., Reichstein, M., Baldocchi, D., Law, B. E., Papale, D., Soussana, J.-F., Ammann, C., Buchmann, N., Frank, D., Gianelle, D., Janssens, I. A., Knohl, A., Köstner, B., Moors, E., Roupsard, O., Verbeeck, H., Vesala, T., Williams, C. A., & Wohlfahrt, G. (2009). Temporal and among-site variability of inherent water use efficiency at the ecosystem level. *Global Biogeochemical Cycles*, *23*(2). https://doi.org/10.1029/2008GB003233

Brunsell, N. A., Nippert, J. B., & Buck, T. L. (2014). Impacts of seasonality and surface heterogeneity on water-use efficiency in mesic grasslands. *Ecohydrology*, *7*(4), 1223–1233. https://doi.org/10.1002/eco.1455

Canadell, J., Jackson, R. B., Ehleringer, J. B., Mooney, H. A., Sala, O. E., & Schulze, E.-D. (1996). Maximum rooting depth of vegetation types at the global scale. *Oecologia*, *108*(4), 583–595. https://doi.org/10.1007/BF00329030

Chescheir, G. M., Skaggs, R. W., & Amatya, D. M. (2008). Hydrologic Impacts of Converting Grassland to Managed Forestland in Uruguay. *Improving Water Quality and Environment Conference Proceedings*. 21st Century Watershed Technology, Concepcion, Chile. https://www.srs.fs.usda.gov/pubs/ja/ja_chescheir005.pdf

Coll, J. (2019). *Temporal Evapotranspiration Aggregation Method (TEAM)*. http://www.hydroshare.org/resource/7f43d1ff46d4403495427c59c0e1d790

de Oliveira, G., Brunsell, N. A., Moraes, E. C., Shimabukuro, Y. E., Bertani, G., dos Santos, T. V., & Aragao, L. E. O. C. (2017). Evaluation of MODIS-based estimates of water-use efficiency in Amazonia. *International Journal of Remote Sensing*, *38*(19), 5291–5309. https://doi.org/10.1080/01431161.2017.1339924

de Oliveira, G., Brunsell, N. A., Sutherlin, C. E., Crews, T. E., & DeHaan, L. R. (2018). Energy, water and carbon exchange over a perennial Kernza wheatgrass crop. *Agricultural and Forest Meteorology*, *249*, 120–137. https://doi.org/10.1016/j.agrformet.2017.11.022

Dang, Y., Ren, W., Tao, B., Chen, G., Lu, C., Yang, J., Pan, S., Wang, G., Li, S., & Tian, H. (2014). Climate and Land Use Controls on Soil Organic Carbon in the Loess Plateau Region of China. *PLOS ONE*, *9*(5), e95548. https://doi.org/10.1371/journal.pone.0095548

El-Masri, B., Barman, R., Meiyappan, P., Song, Y., Liang, M., & Jain, A. K. (2013). Carbon dynamics in the Amazonian Basin: Integration of eddy covariance and ecophysiological data with a land surface model. *Agricultural and Forest Meteorology*, *182–183*, 156–167. https://doi.org/10.1016/j.agrformet.2013.03.011

Farley, K. A., Jobbágy, E. G., & Jackson, R. B. (2005). Effects of afforestation on water yield: A global synthesis with implications for policy. *Global Change Biology*, *11*(10), 1565–1576. https://doi.org/10.1111/j.1365-2486.2005.01011.x

HU, Z., YU, G., FU, Y., SUN, X., LI, Y., SHI, P., WANG, Y., & ZHENG, Z. (2008). Effects of vegetation control on ecosystem water use efficiency within and among four grassland ecosystems in China. *Global Change Biology*, *14*(7), 1609–1619. https://doi.org/10.1111/j.1365-2486.2008.01582.x

INUMET. (n.d.-a). *Estadisticas climatologicas*. https://www.inumet.gub.uy/clima/estadisticas-climatologicas

Jackson, R. B., Randerson, J. T., Canadell, J. G., Anderson, R. G., Avissar, R., Baldocchi, D. D., Bonan, G. B., Caldeira, K., Diffenbaugh, N. S., Field, C. B., Hungate, B. A., Jobbágy, E. G., Kueppers, L. M., Nosetto, M. D., & Pataki, D. E. (2008). Protecting climate with forests. *Environmental Research Letters*, *3*(4), 044006. https://doi.org/10.1088/1748-9326/3/4/044006

Law, B. E., Falge, E., Gu, L., Baldocchi, D. D., Bakwin, P., Berbigier, P., Davis, K., Dolman, A. J., Falk, M., Fuentes, J. D., Goldstein, A., Granier, A., Grelle, A., Hollinger, D., Janssens, I. A., Jarvis, P., Jensen, N. O., Katul, G., Mahli, Y., … Wofsy, S. (2002). Environmental controls over carbon dioxide and water vapor exchange of terrestrial vegetation. *FLUXNET 2000 Synthesis*, *113*(1), 97–120. https://doi.org/10.1016/S0168-1923(02)00104-1

Monteith, J. L. (1988). Does transpiration limit the growth of vegetation or vice versa? *Journal of Hydrology*, *100*(1), 57–68. https://doi.org/10.1016/0022-1694(88)90181-3

Nosetto, M. D., Jobbágy, E. G., & Paruelo, J. M. (2005). Land-use change and water losses: The case of grassland afforestation across a soil textural gradient in central Argentina. *Global Change Biology*, *11*(7), 1101–1117. https://doi.org/10.1111/j.1365-2486.2005.00975.x

Nosetto, M. D., Jobbagy, E. G., Brizuela, A. B., & Jackson, R. B. (2011). The Hydrologic Consequences of Land Cover Change in Central Argentina. *Agriculture, Ecosystems and Environment*.

Scanlon, B., Keese, K., Bonal, N., Deeds, N., Kelley, V., & Litvak, M. (2005). *Evapotranspiration Estimates with Emphasis on Groundwater Evapotranspiration in Texas*. https://www.twdb.texas.gov/groundwater/docs/BEG_ET.pdf

Tang, X., Li, H., Desai, A. R., Nagy, Z., Luo, J., Kolb, T. E., Olioso, A., Xu, X., Yao, L., Kutsch, W., Pilegaard, K., Köstner, B., & Ammann, C. (2014). How is water-use efficiency of terrestrial ecosystems distributed and changing on Earth? *Scientific Reports*, *4*(1), 7483. https://doi.org/10.1038/srep07483

Tian, H., Chen, G., Liu, M., Zhang, C., Sun, G., Lu, C., Xu, X., Ren, W., Pan, S., & Chappelka, A. (2010). Model estimates of net primary productivity, evapotranspiration, and water use efficiency in the terrestrial ecosystems of the southern United States during 1895–2007. *Managing Landscapes at Multiple Scales for Sustainability of Ecosystem Functions*, *259*(7), 1311–1327. https://doi.org/10.1016/j.foreco.2009.10.009

Wilcox, Bradford. P., Le Maitre, D., Jobbagy, E., Wang, L., & Breshears, D. D. (2017). Chapter 3: Ecohydrology: Processes and Implications for Rangelands. In *Rangeland Systems* (pp. 85–127). Springer Nature.

Zhang, L., Dawes, W. R., & Walker, G. R. (2001). Response of mean annual evapotranspiration to vegetation changes at catchment scale. *Water Resources Research*, *37*(3), 701–708. https://doi.org/10.1029/2000WR900325

Zhu, X., Yu, G., Wang, Q., Hu, Z., Han, S., Yan, J., Wang, Y., & Zhao, L. (2014). Seasonal dynamics of water use efficiency of typical forest and grassland ecosystems in China. *Journal of Forest Research*, *19*(1), 70–76. https://doi.org/10.1007/s10310-013-0390-5

Chapter 5: Conclusion

The research findings in this dissertation are summarized in Figure 1, a diagram representing the human-environmental relationships in ranch management as ranchers deal with the pressures of woody encroachment and precipitation variability. Ranchers in the Colonia Juan Gutiérrez face real threats that are predicted to increase with the effects of climate change. These effects include an increase in floods and thunderstorms, and an increase in summer and winter temperatures. An increase in flooding would aggravate the already damaging seasonal flooding events that make livestock water supply difficult due to lack of accessibility to natural water bodies (chapter 3). The same goes for an increase in summer temperatures as it would add to the difficulties of livestock water supply management during droughts (chapter 3). In addition to climate change, ranchers in the Colonia Juan Gutiérrez are vulnerable to the expansion of forestry plantations located in the headwaters of the tributaries to the lower Queguay Grande watershed (chapter 3). Forestry plantations of pine and eucalyptus species have been shown to increase storm peaks and increase floods after harvest (chapter 2). Intentional or unintentional spread of these exotic woody species may lead to woody encroachment, which if left unmanaged, could jeopardize the integrity of the temperate grasslands in the Colonia Juan Gutiérrez (chapter 4). Unfortunately, the increasing winter temperatures and increase in magnitude of precipitation associated with climate change are believed to create optimal conditions for woody ecosystems (chapter 2). Therefore, the pressures that already affect ranchers in the Colonia Juan Gutiérrez are further compounded by the effects that climate change is predicted to bring.

Ranchers in the Colonia Juan Gutiérrez have built a strong adaptive capacity to challenges associated with livestock water supply, however, the need to increase adaptation calls for an increase in support from conservation and governmental organizations. Conversations among ranchers and non-profit conservation organizations like Alianza del Pastizal concerning woody encroachment are not as prevalent as they could be given the problems associated with the expansion of forestry plantations. This dissertation provides a detailed look at the perceptions that ranchers in the Colonia hold on practices that could help with these challenges.

Given that ranchers in the Colonia Juan Gutiérrez are located in the floodplain of the Queguay Grande river and the Queguay Chico river, some of them have access to natural water bodies and use them as their main livestock watering source. Other ranchers, however, do not have access to the main rivers but do have access to other natural water bodies like streams or ponds. At the same time, there are other ranchers who do not have access to surface water but have installed wells to gain access to groundwater. Ranchers who did not rely completely on natural water bodies as a livestock watering source installed artificial watering systems.

In chapter 3 we outlined the results of an analysis where we presented ranchers with two practices related to water resource management to get their perspectives on which practices they would adopt and implement regardless of the cost. We learned that all ranchers believe that caring for natural water bodies for later use is important, however, those ranchers who have a higher dependency on natural water bodies for livestock water supply ranked this practice higher. Ranchers who were early in the installation of artificial water distribution systems or needed extensive maintenance in their systems ranked the strategic placement of water distribution systems higher. Ranchers who relied completely on natural water bodies for livestock water supply acknowledged that if financial support was available, they would install artificial watering systems. Therefore, although ranchers have adapted to their property’s access to natural water bodies for livestock watering, they call for help from extension agents associated with

Alianza del Pastizal, AUGAP, Plan Agropecuario or RAFMU to help them connect with opportunities for projects that provide subsidies or financial incentives from governmental institutions.

Chapter 4 provided evidence of the effects that the forestry plantations are having on the Colonia Juan Gutiérrez properties. We used TEAM, a Google Earth Engine tool to calculate the water use efficiency (WUE), gross primary productivity (GPP), and evapotranspiration (ET) of the vegetation types of the forestry plantations, the Rincon de Perez conservation area, and the properties in the Colonia. We used WUE as a proxy for land cover change and found variation in the water fluxes of the vegetation types in each one of the three sites. Vegetation types in the conservation area and the properties in the Colonia Juan Gutiérrez had clear seasonal WUE patterns, whereas the vegetation types in the forestry plantations had no clear WUE patterns. This phenomenon may have been caused by the harvesting events that occurred in the 2001-2018-time frame, an example of which can be evidenced in the satellite photographs displayed in chapter 2. A comparison between GPP values in all three sites indicated that vegetation types in the properties are behaving similarly to that of the forestry plantations. This is problematic, because it has been assumed that the conservation practices used to manage the properties would result in vegetation types that would more closely resemble the undisturbed conditions of the conservation area, rather than the highly disturbed vegetation types of the forestry plantations. Therefore, for the purpose of this study, the conservation area WUE and GPP values are used as benchmarks to compare the integrity of the vegetation types in the Colonia Juan Gutiérrez properties. Resembling the forestry plantations may mean that invasive woody vegetative species from the forestry plantations are already present in the Colonia Juan Gutiérrez properties and this is the reason why WUE and GPP values are resembling those in the forestry plantations.

In chapter 2 we outlined the results of an analysis where we presented ranchers with five practices related to woody encroachment management to obtain their perspectives on which practices they would adopt and implement regardless of the cost. We found that ranchers from the Colonia Juan Gutiérrez prefer management regimes that lean towards coexisting with woody species instead of eradicating encroaching woody vegetation. We identified targeted grazing as the woody encroachment management approach that is preferred by ranchers based on their socioeconomic and cultural context. Therefore, livestock species traditionally raised on ranches in this area of the country are used in management, and practices that use herbicides and heavy machinery are avoided. It is necessary for ranchers to become educated and efficient in implementing targeted grazing to manage the encroachment of exotic species like pine and eucalyptus potentially coming from forestry plantations, however, additional research is needed to evaluate the effectiveness and ecological consequences of targeted grazing. Some ranchers are already practicing targeted grazing, which indicates a positive cultural alignment. Additionally, several ranchers have implemented practices promoted by the Alianza del Pastizal, which dovetail well with targeted grazing and help to facilitate adoption and implementation of these practices. For example, paddock fencing used for rotational grazing to manage woody encroachment can simultaneously aid in the management of water distribution systems.

This dissertation will be shared electronically with the ranchers of the Colonia Juan Gutiérrez, and Alianza del Pastizal. A visit to the Colonia Juan Gutiérrez will be scheduled when the COVID-19 pandemic ends. During this visit, packets will be distributed to ranchers with hard copies of publications that result from this study, maps of individual properties, WUE analyses, and other materials that may be useful for decision-making purposes. A gathering to present these results will be organized in collaboration with Aves Uruguay, which is the local Alianza representative, AUGAP, and the Sociedad de Fomento Rural de la Colonia Juan Gutiérrez. Meanwhile, virtual presentations of this dissertation will be offered to the organizations that helped with the development of this dissertation and all of those interested in disseminating this information. Recent discussions in Uruguayan agricultural circles[7] call for financially accessible and safe methodologies for data collection and information dissemination. I also offer my participation in training sessions that could involve the user-friendly open-source Google Earth Engine tools such as Global Forest Watch for the satellite analyses used in this dissertation. Future projects involve the establishment of a potential rancher exchange program through the Kansas State University extension program headed by Dr. Carol Baldwin. The purpose of this exchange would be to travel with Kansas ranchers to Uruguay, and to bring Uruguayan ranchers from the Colonia Juan Gutiérrez to Kansas for cultural and technical exchanges. It is my hope that the political and global public health conditions stabilize to embark on this journey.

[7] Carriquiry, E. (2020, November 3). *Gestión del Pasto: Más que un proyecto, una nueva visión del campo* [Facebook Live]. https://fb.watch/1P_i1jITCi/

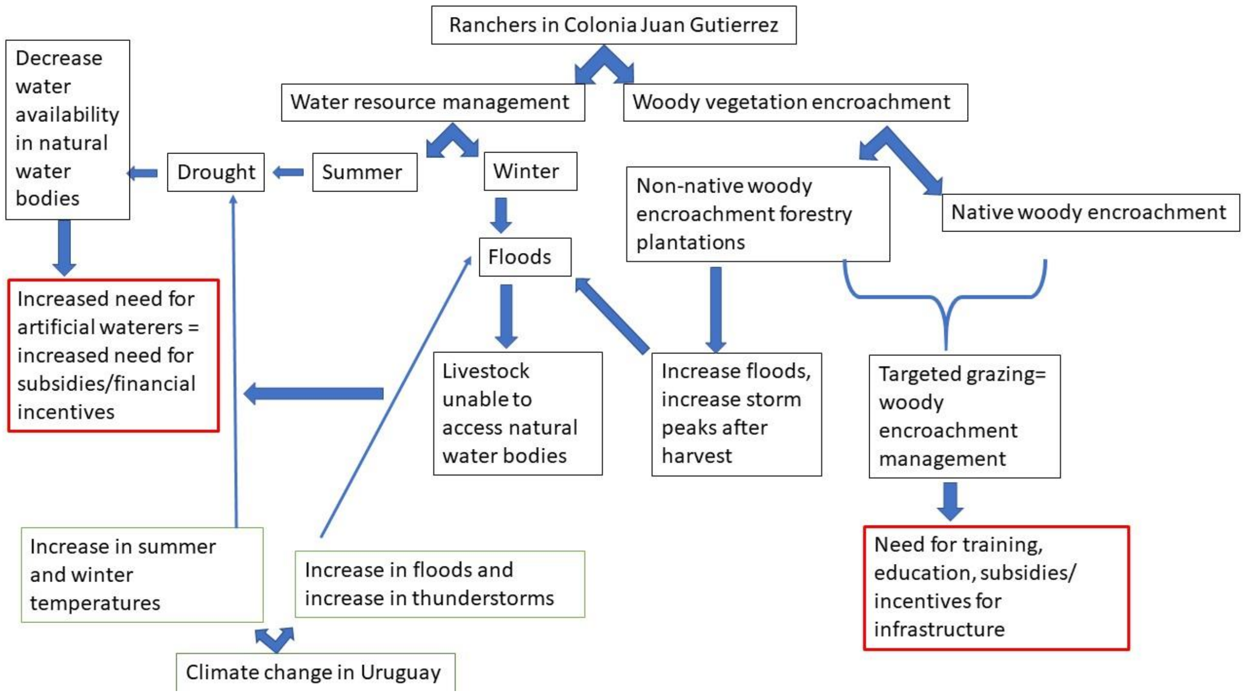


Figure 1. The human-environment ranching management system in the Colonia Juan Gutiérrez.