UNIVERSIDAD DE LA REPÚBLICA
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LA GESTIÓN ESPACIO-TEMPORAL DEL PASTOREO Y SU RELACIÓN CON EL RESULTADO PRODUCTIVO DE LOS SISTEMAS CRIADORES SOBRE CAMPO NATURAL

por

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RESUMEN

El objetivo del presente estudio fue explicar y cuantificar a escala de sistemas ganaderos familiares (SGF) las relaciones entre los modelos de gestión del pastoreo, el nivel de adopción de prácticas de manejo y los niveles de altura y oferta de forraje (AF y OF), condición corporal (CC), producción y consumo de forraje y de energía (CR y CEM), nivel de hormonas metabólicas (IGF-1, insulina y leptina) y los resultados reproductivos y productivos durante dos años (2017-2019). SGF con diferente trayectoria de coinnovación fueron seleccionados como estudio de caso y caracterizados de acuerdo a su gestión espacio-temporal del pastoreo como Gestor espacio-temporal (GET) y No Gestor Tradicional (NGT) y se calculó el nivel de adopción de prácticas en la cría vacuna (IPC, escala del 1-100). El SGF definido como GET-IPC85 registró una AF de 6,2 ± 1,5 cm, OF de 5,4 ± 0,3 kgMS $kgPV^{-1}$ y CC de 4,9 ± 0,3 puntos, tasa de preñez del 100 % y 213 kilogramos (kg) de ternero destetado por vaca entorada asociados a una producción de 132 kg de carne vacuna por hectárea en promedio de dos años. Dichos niveles fueron 90 y 58 % superior en kg de terneros destetados por vaca entorada y carne vacuna por hectárea respectivamente comparada con NGT. Las GET estuvo asociada a diferencias de 86 % o 3,25 cm en AF ($P < 0,05$), de 1 punto superior de CC ($P < 0,05$) y niveles 47 % superiores de CEM y 79 % ($P < 0,05$) de IGF-1 al parto, lo que contribuye a explicar un mayor status nutricional-metabólico y partición de nutrientes hacia producción de terneros en GET. La gestión espacial y temporal del pastoreo de CN y 18 % de pasturas mejoradas, integrado a prácticas de la cría vacuna en una trayectoria de 5 años de coinnovación, lograría acoplar el balance de energía del sistema durante el ciclo de cría y mejorar los resultados productivos a niveles sustentables. La gestión espacio-temporal del pastoreo es una herrameinta de intensificación agroecológica, sin modificar recursos, puede mejorar los niveles de producción y sostenibilidad de los SGF criadores sobre campo natural.

Palabras clave: intensificación agroecológica, co innovación, cría vacuna

SPATIAL-TEMPORAL GRAZING MANAGEMENT AND PRODUCTIVE RESULT AT COW-CALF SYSTEMS ON CAMPOS GRASSLAND

SUMMARY

The aim of this study was to explain and quantify at beef cow family farm systems (FS) the relationships between grazing management models, the level of adoption of management practices and the levels of forage height and allowance (FH and FA), cow body condition score (BCS), forage growth (FG) and cow energy intake (MEI), metabolic hormones (IGF-1, insulin and leptin) and the reproductive and productive results during two years (2017-2019). FS with different trajectories of co-innovation were selected as a case study, characterized by their structure and grazing space-temporary management as Spatio-temporal Manager (STM) and Traditional Non Manager (TNM) and an indicator of level of cow-calf practices adoption was calculated (IPC, scale of 1-100). The STM-IPC85 registered a FH of 6.2 ± 1.5 cm, FA of 5.3 ± 1.0 kgMS $kgPV^{-1}$ and BCS of 4.9 ± 0.3 points, pregnancy rate of 100 % and 213 kilograms (kg) of weaned calf per breeding cow (205 days postpartum) associated to 132 kg of beef meat per hectare for the two-year average. These results were 90 and 58 % higher in kg of weaned calf per breeding cow and beef meat per hectare respectively compared to TNM. STM was associated to differences of 86 % or 3.25 cm in FH ($P < 0.05$), 1 point of BCS ($P < 0.05$), 47 % MEI ($P < 0.05$) and 79 % ($P < 0.05$) of IGF-1 at calving, which contributed to explain a higher nutritional-metabolic status and nutrient partitioning towards calf production. Spatial and temporal grazing management integrated to jerarquized cow-calf practices in a 5 years co-innovation pathway, achieved to couple most part of the energy balance and improved FS productive results. Spatio-temporal grazing management is an agroecological intensification management practice that, without modifying resources, can improve productive levels and sustainability at cow-calf FS on Campos grassland.

Keywords: agroecological intensification, participatory learning, cow-calf

1. INTRODUCCIÓN

1.1 LA CRÍA VACUNA EN EL RÍO DE LA PLATA

Los sistemas ganaderos sobre campo natural (Allen et al., 2011) constituyen la principal actividad económica y social del sector agropecuario del Río de la Plata. El campo natural ocupa 700.000 km^2 en la región con más de 4000 especies nativas C3 y C4 (Soriano, 1992), lo que constituye un potencial de biodiversidad, a la vez que provee importantes servicios ecosistémicos a la región y su comunidad (Paruelo et al., 2010).

En Uruguay el campo natural constituye el 90 % del recurso forrajero y ocupa 12,4 millones de hectáreas (DIEA, 2014) con un 51 % de los ganaderos orientados a la cría vacuna, y un 63 % de los criadores, 15.675 (DIEA, 2014), definidos como sistemas ganaderos familiares (SGF) (Piñeiro, 1985).

Durante la última década, la producción de carne promedio de los SGF ha sido de 70 kilogramos (kg) de carne ha^{-1} $año^{-1}$ con una tasa de destete del 64 % (DIEA, 2014). Estos niveles de producción se asocian con un ingreso neto limitado, lo que resulta en una ganadería familiar sobre campo natural de pobre resultado económico, reducida sustentaibilidad y vulnerable a cambios climáticos. A su vez por contexto regional, la actividad ganadera y el bioma campo natural se ven amenazados frente a la creciente forestación y agricultura, lo que afecta económica, social y ecológicamente a la región (Modernel et al., 2016, Carvalho y Batello 2009). Concretamente Nabinger et al. (2000) reportan una disminución del campo natural del 1 % anual en las últimas cuatro décadas en la región.

Los limitados resultados productivos a nivel nacional han sido explicados principalmente por elevados niveles de carga animal y limitada gestión espacio temporal del pastoreo e implementación de prácticas de manejo de la cría vacuna. La falta de gestión del pastoreo a escala de espacio (por potrero y manejo de altura de forraje) y de tiempo (estacional en el ciclo productivo) contribuyen a explican los bajos niveles de disponibilidad, oferta y consumo de forraje, el balance energético negativo (BEN), la pobre condición corporal (CC) al parto de las vacas de cría, el largo período de anestro posparto, la baja probabilidad de preñez y de peso vivo de terneros al destete (Do Carmo et al., 2016, Soca y Orcasberro 1992, Short et al., 1990), y gran parte de los limitados resultados productivos, físicos y económicos de los sistemas criadores sobre campo natural (Paparamborda, 2017).

Un enfoque sistémico de gestión predial que integre el manejo de la intensidad de pastoreo por potrero y estación, con las prácticas de manejo de bajo costo, ha sido la propuesta técnica de innovación del grupo de ecología del pastoreo de la Facultad de Agronomía (Universidad de la República, Uruguay) desde hace ya más de una década para abordar esta problemática y mejorar la productividad y sostentabilidad económica, social y ecológica de los SGF sobre campo natural (Soca et al., 2007, Pereira y Soca 1999, Soca y Orcasberro 1992).

1.2 MANEJO DE LA INTENSIDAD DE PASTOREO

El balance de energía del sistema criador pastoril resulta del acople entre la variabilidad estacional de producción de forraje y la de los requerimientos de energía animal según su estado fisiológico y categoría a lo largo del año. Este concepto fue llevado a una propuesta técnica por Soca y Orcasberro (1992) de manejo dinámico de altura del forraje y CC por estación, buscando acoplar los requerimientos energéticos de la vaca de cría en los diferentes estados fisiológicos y la producción de forraje estacional del campo natural para maximizar el consumo y balance de energía y mejorar los resultados reproductivos del rodeo de cría (Figura 1).

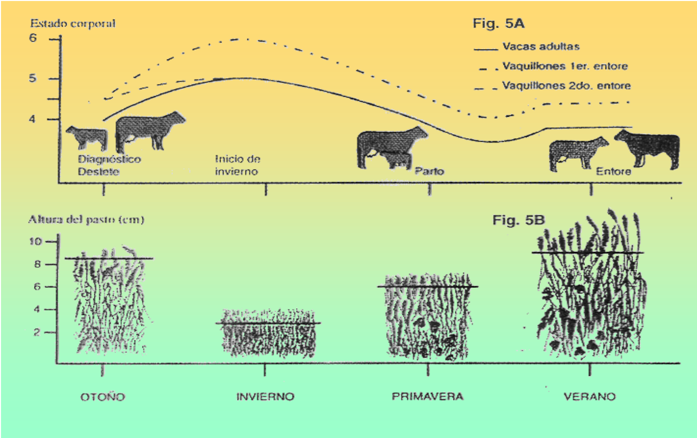

Figura 1. Propuesta de Manejo del rodeo de Cría en base a la evolución del estado corporal, la altura del pasto en los potreros de campo natural y aplicación del destete temporario a inicio del entore (Soca y Orcasberro, 1992).

Esta primera propuesta técnica (Soca y Orcasberro, 1992) consiste en manejar la asignación de forraje en otoño con una altura del pasto de 8 cm de forma de alcanzar una CC de la vaca de cría de 5 puntos (Vizcarra et al., 1986) para esta estación, permitiendo que las vacas lleguen al parto en la primavera con una CC no inferior a 4 puntos, asumiendo la pérdida asociada a la baja disponibilidad de forraje en el invierno. La CC al parto es el predictor más importante de la probabilidad de preñez futura (Hess et al., 2005, Trujillo et al., 1999, Short et al., 1990), a su vez vacas con mayor CC al parto ovulan más tempranemente en el posparto (Meikle et al., 2004, Quintans et al., 2010, Soca et al., 2013b). Por lo tanto lograr un adecuado nivel de reserva corporal al parto, sumado a la buena disponibilidad de forraje en primavera en nuestros sistemas, permitirá mantener un nivel de energía suficiente para cubrir el período de alta demanda energética durante parto-lactancia, y retomar la ciclicidad ovárica en el siguiente próximo entore en verano, aumentando la probabilidad de preñez del rodeo de cría lo que determina gran parte de los resultados productivos del sistema de cría (Short et al., 1990).

El manejo de la intensidad de pastoreo a través del manejo de la altura y oferta de forraje para cubrir los requerimientos energéticos según el estado fisiológico de la vaca de cría ha demostrado ser una herramienta que, sin modificar los costos, aumenta la producción animal y mejorar los niveles de ingreso de los sistemas ganaderos sobre campo natural (Soca et al., 2013d, Soca et al., 2007). Durante los últimos años, la asignación de campo natural al rodeo de cría ha sido orientada en base al impacto del cambio en la oferta de forraje sobre los niveles de productividad. El incremento de la oferta de forraje en campo natural entre 2,5 (similar al promedio nacional en los SGF, Paparamborda 2017, Ruggia et al., 2015) y 5 kgMS $kgPV^{-1}$ mejoró la producción de carne por superficie (Carvalho et al., 2008, Soca et al., 2007) incluso, sin modificar la carga animal (Do Carmo et al., 2018). Con niveles de OF de 5 kgsMS $kgPV^{-1}$ se mejoró la producción, el consumo y la eficiencia en el uso del forraje para la cría vacuna, aumentando la eficiencia y los resultados productivos del sistema de cría sobre campo natural (Claramunt et al., 2018, Do Carmo et al., 2016, Carvahlo et al., 2008).

En un sistema pastoril el circuito de pastoreo implica la combinación de animales y potreros en el tiempo y en el espacio, donde la toma de decisiones del productor ganadero (con diferente grado de explicitez) está basada principalmente en sus objetivos y los de su familia, en la estructura y organización del sistema, e integra información del estado de los animales, del forraje y los potreros, con la influencia de variables climáticas y de mercado, para decidir y accionar sobre el uso de los potreros en el tiempo (Duru y Hubert, 2003; Figura 2).

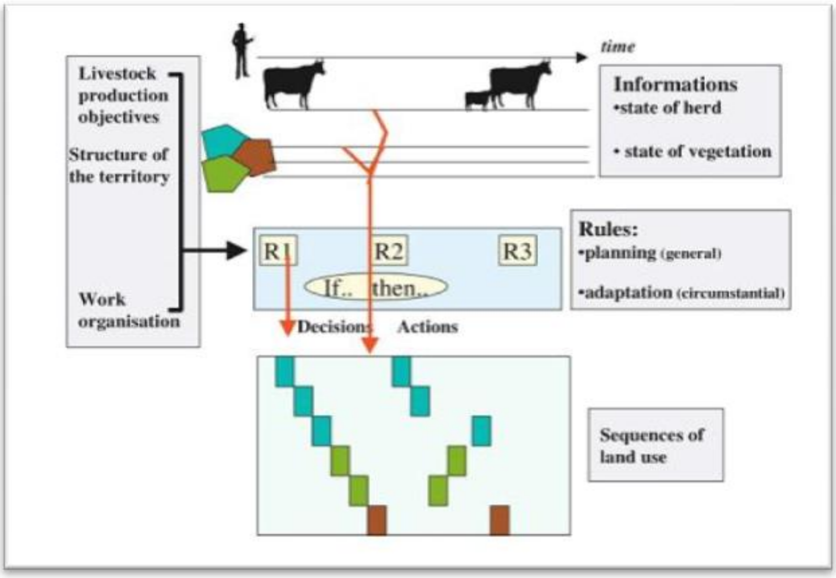

Figura 2: Modelo conceptual de comportamiento de un productor ganadero, basado en la integración de información del sistema, los animales y el forraje y dos niveles de reglas (general y circunstancial) para la toma de decisiones y acciones en el uso por potrero y entre potreros en el tiempo, para un sistema pastoril (Duru y Huber, 2003).

1.3 PRÁCTICAS EN LA CRÍA VACUNA

Existen numerosas prácticas de manejo de la cría vacuna con el objetivo de controlar el flujo y balance de energía del rodeo de forma eficiente, principalmente buscan acoplar los requerimientos energéticos del rodeo al consumo y re-direccionar la energía consumida hacia reproducción y producción de kilogramos de ternero. Dichas prácticas pueden clasificarse en a) estratégicas, como el control de la época de entore y partos; b) para asistir la toma de decisiones, como la clasificación por CC y la implementación del diagnóstico de actividad ovárica y gestación; y c) tácticas, como la suplementación o control del amamantamiento para ser aplicadas oportunamente (Paparamborda, 2017).

Paparamborda (2017) propuso un Índice de prácticas de manejo de la cría (IPC) como un indicador numérico del nivel de adopción de prácticas por parte del productor que va del 0 al 100, donde a cada práctica se le adjudica un valor relativo ponderado por expertos, cuya sumatoria resulta en el IPC final para ese sistema.

La adopción de prácticas en la cría vacuna del Uruguay y Argentina resulta limitada (Oyhantçabal 2003, Pereira 2003). En Uruguay el 41 % de los SGF aun practican entore continuo, el 58 % clasifica el rodeo por CC y sólo el 35 % aplica prácticas de control del amamantamiento (Paparamborda, 2017). Esta información refleja que a pesar de la evidencia generada por la ciencia sobre la estrecha y positiva relación entre la aplicación de técnicas de manejo en la cría vacuna de bajo costo y la mejora de la producción animal, su aplicación es limitada (Paparamborda 2017, Gómez-Miller y Saravia 2016, Oyhantçabal 2003, Pereira 2003).

Esta información confirma la necesidad de un trabajo con base en un abordaje participativo y sistémico que incluya a técnicos, investigadores, productores y administradores de políticas públicas para lograr la transición a SGF sustentables sobre campo natural (Coquil et al., 2018).

1.4 RESPUESTA ADAPTATIVA Y SOSTENIBILIDAD DE LOS SISTEMAS

La sostenibilidad de un sistema criador pastoril en el Río de la Plata puede estar amenazada frente a eventos de cambio climático (Modernel et al., 2019). La producción de forraje del campo natural es estacional y es explicada en gran parte por la disponbilidad de agua en el suelo y la temperatura (Berretta et al., 2000) lo que, asociado a manejos tradicionales de sobrepastoreo con limitada producción de forraje, reducen la capacidad de respuesta adaptativa del sistema frente a la eventualidad de períodos de sequía cada vez más frecuentes en estas regiones (Modernel et al., 2019). La capacidad de adaptación de un sistema ganadero pastoril frente a un evento restrictivo se contruye en el tiempo, debido a que en parte es explicada por la cantidad y biodiversidad del forraje disponible en los potreros (Modernel et al., 2019), el estado fisiológico, metabólico y reservas corporales de las vacas de cría (revisado por Meikle et al., 2018, Blanc et al., 2006), aunque depende también de la severidad, duración y frecuencia de los eventos restrictivos (Chilliard et al., 1998).

El mecanismo adaptativo de la vaca de cría está basado en cambios en el comportamiento de pastoreo y en el incremento de la eficiencia biológica de ciertas funciones metabólicas tisulares en rumen e intestino y en el hígado con mejora en la eficiencia del metabolismo del tejido adiposo en momentos de alta demanda energética (Chilliard et al., 2006).

En la regulación endócrina, la principal respuesta hormonal de las vacas de cría está dirigida a mantener la relación entre la homeostasis para la supervivencia y teleoforesis para la producción de terneros, a través de la movilización coordinada y secuencial de las reservas corporales, principalmente del tejido adiposo (Chilliard et al., 1998). En los sistemas pastoriles la gestión de la oferta de forraje determina el consumo y balance de energía, los niveles de reserva de energía y la respuesta endócrina del rodeo de cría (Claramunt et al., 2018, Do Carmo et al., 2016, Carriquiry et al., 2013, Soca et al., 2013a). Donde la mejora del nivel nutricional y metabólico están asociados a un aumento de los niveles circulantes en sangre de las hormonas IGF-1, insulina (Claramunt et al., 2018, Mapfumo et al., 2017, Laporta et al., 2013, Meikle et al., 2013, Soca et al., 2013a, Astessiano et al., 2012 y 2013) y leptina (Blanc et al., 2006) que promueven las señales anabólicas (Hess et al., 2005) para la regulación de la actividad de las enzimas que intervienen en la rutas metabólicas hacia producción y reserva de tejidos en el animal.

Los diferentes niveles de respuesta adaptativa de la vaca de cría o nivel de robustez pueden estar asociados indirectamente a criterios de selección del productor basado en la eficiencia de utilización de la energía para reproducción y producción de kilogramos de ternero frente a una restricción de forraje de tiempo limitado (Friggens et al., 2017). La adaptación metabólica de las vacas de cría puede constituir una herramienta de resiliencia animal que contribuya, entre otras, a la sostenibilidad de los sistemas criadores (Noziéres et al., 2009) sobre campo natural frente a eventos de limitida producción y disponibilidad de forraje como sucede en nuestros sistemas durante los eventos de sequías (Figura 3).

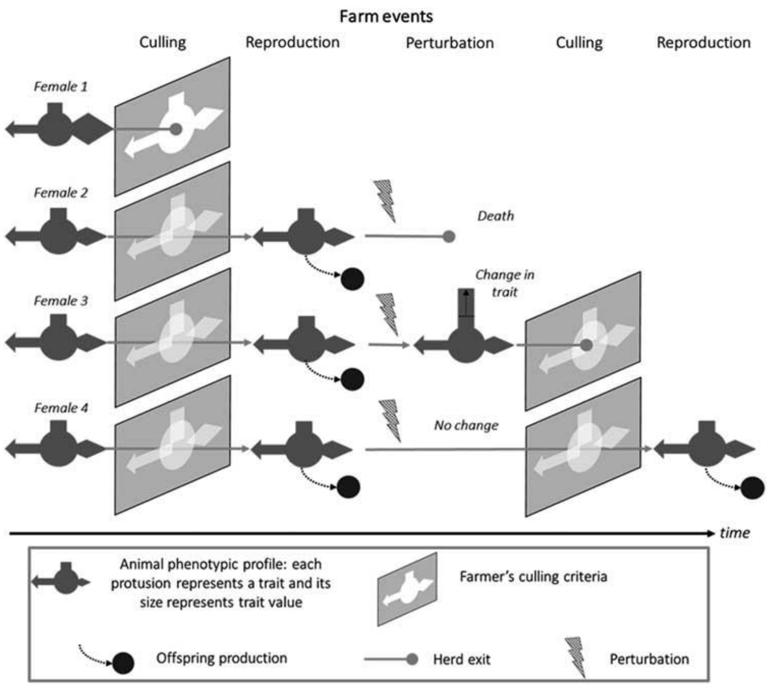

Figura 3. Representación esquemática de la trayectoria de 4 tipos de animales asociados a su diferente capacidad de respuesta o nivel de robustez frente a una perturbación ambiental, que determina su permanencia en el rodeo según el criterio de refugo del productor (las figuras geométricas representan las características animales que deben encastrar en la silueta-herraje que representa el criterio de selección del productor, mientras la esfera sólida menor representa la producción de una cría y la figura del rayo un evento de perturbación ambiental) (Friggens et al., 2017).

1.5 DIÁLOGO ENTRE INVESTIGACIÓN PREDIAL Y EXPERIMENTAL

El dialogo entre los resultados experimentales del grupo de Ecología del Pastoreo de Facultad de Agronomía (Universidad de la República) y el funcionamiento predial promueven un escenario de generación y retroalimentación de información científica pertinente y aprendizaje colectivo, con el objetivo de apoyar un modelo de intensificación agroecológica de la producción y mejora en sostenibilidad de sistemas ganaderos criadores sobre campo natural. A nivel predial, Paparamborda (2017) caracterizó a 272 SGF de la región Basalto y Sierra del Este en una tipología basada en indicadores estructurales y funcionales de los SGF (ej. área propia y arrendada total y de pastoreo, porcentaje de área mejorada, carga animal, relación lanar/vacuno) no encontrando diferencias productivas entre predios. Sin embargo, cuando a los mismos SGF se los agrupó de acuerdo a la gestión espacio temporal del pastoreo (de acuerdo al control y duración del entore, patrón de utilización de poteros y carga animal por hecatrea) en grupos como No Gestor, Gestor y Gestor Espacio-Temporal, se encontraron diferencias de 30 por ciento (91 vs 70 kg ha^{-1} $año^{-1}$) en la producción de carne por unidad de superficie a favor de los gestores espacio-temporal ($P < 0,05$). Esto confirma que la cantidad de kilogramos de carne que produce un sistema por unidad de superficie en campo natural está relacionada con el manejo de los recursos en el tiempo y en el espacio, lo cual involucra el manejo de cada potrero de acuerdo a la altura de pasto, estación del año, CC, edad y estado fisiologógico de las vacas, de manera de lograr el consumo y acople del balance de energía que permita mejorar la performance animal (Duru y Hubert 2003, Soca y Orcasberro 1992).

El Instituto Nacional de Investigación Agropecuaria (INIA) llevó a cabo un trabajo de investigación durante 3 años en 7 SGF sobre campo natural en Sierra del Este (Uruguay), con un abordaje de co innovación (Dogliotti et al., 2014). Mediante el rediseño acordado entre cada productor y el técnico predial, se registró un aumento promedio en la OF entre 3,3 a 5,6 kgMS kg

PV^{-1}, de la producción de carne de 99 a 122 kg ha^{-1}, y los kilogramos de ternero destetado por vaca entorada de 107 a 140 al finalizar el proyecto (Ruggia et al., 2015). Este trabajo con enfoque participativo, generó un importante antecedente nacional que relacionó el rediseño técnico predial basado en la gestión espacio temporal del pastoreo y el ajuste de la carga y/o relación lanar/vacuno, para aumentar la cantidad y oferta de forraje y los resultados productivos, económico y sociales, sin impacto negativo ambiental (Aguerre et al., 2018, Albicette et al., 2017, Blumetto et al., 2019).

La información generada a nivel experimental y de sistemas ha significado un gran aporte para ser incorporadas en la toma de decisiones y para generar un modelo de gestión sistémico y sustentable que integre la dimensión social, económica, productiva y ambiental en sistemas criadores sobre campo natural. No obstante, no disponemos de coeficientes que cuantifiquen y expliquen a escala predial la relación entre la gestión del pastoreo integrada con las prácticas prediales y los niveles estacionales de cantidad y oferta de forraje (OF), condición corporal (CC), crecimiento y consumo de forraje y respuesta endócrina, asociados a los resultados de tasa de preñez y producción de kilogramos de terneros por vaca entorada y kilogramos de carne vacuna por superficie en SGF sobre campo natural. Explicar la relación entre las decisiones de manejo de los productores y la respuesta de variables de estado y de procesos planta-animal en los sistemas, puede contribuir como insumo en la toma de decisiones de productores, extensionistas, investigadores y responsables de políticas públicas para el rediseño sistémico, agroecológico y sostenible de los SGF sobre campo natural.

1.6 HIPÓTESIS

Los sistemas ganaderos que gestionan la intensidad de pastoreo de las vacas de cría en el tiempo y en el espacio integrado a prácticas de manejo estratégicas dirgidas a acoplar el balance de energía del sistema, mejoran los niveles de altura y oferta de forraje, la condición corporal, la producción y consumo de forraje y la respuesta endócrina de las vacas de cría y como consecuencia incrementan los kilogramos de ternero destetados por vaca entorada y la producción de carne por unidad de superficie predial sin cambio en el nivel de recursos prediales asignados a la cría vacuna.

Dichos cambios, se explicarían por los niveles que asumen las principales variables de estado (cantidad de forraje, condición corporal y kilos de ternero destetado; Do Carmo et al., 2016) lo cual contribuiría a explicar la capacidad de los SGF de atenuar los efectos detrimentales de la variabilidad climática.

1.7 OBJETIVO GENERAL

Cuantificar y explicar a escala de sistemas de producción las relaciones entre los modelos de gestión del pastoreo, las prácticas de manejo aplicadas a la cría vacuna y los niveles de cantidad y oferta de forraje, la condición corporal, la producción y consumo de forraje y los niveles de hormonas metabólicas de las vacas de cría, de manera de explicar los resultados productivos.

Aportar información a la toma de decisiones que permita mejorar la sostenibilidad y resiliencia de los sistemas de cría vacuna sobre campo natural.

1.7.1 Objetivos específicos

i. Cuantificar y explicar la relación entre los niveles de gestión del pastoreo y adopción de prácticas de la cría vacuna (IPC) con los niveles estacionales de las variables de estado que definen al sistema de cría vacuna en campo natural: altura de forraje, condición corporal y kilogramos de ternero destetado por vaca entorada, asociados a los resultados de tasa de preñez y producción de kilogramos de carne vacuna por hectárea, durante dos ciclos reproductivos (parto-destete, 2017-2019) en tres SGF de Sierra del Este, Uruguay.

ii. Cuantificar y explicar la relación entre los diferentes niveles de gestión del pastoreo, la adopción de prácticas de la cría (IPC) con los niveles de consumo y crecimiento de forraje, y evolución de concentración sérica de IGF1, leptina e insulina asociados con la tasa de preñez, kilogramos de ternero destetado por vaca entorada y kilogramos de carne vacuna por hectárea producidos durante dos ciclos reproductivos en tres SGF de Sierra del Este, Uruguay.

La tesis se estructura en 4 capítulos centrales. El capítulo 1 corresponde a la introducción con los antecedentes, fundamentación, hipótesis y objetivos del trabajo. El capítulo 2 presenta el artículo científico que responde a los objetivos del trabajo y está redactado según las normas de la revista Agricultural Systems. El capítulo 3 corresponde a la discusión general de los resultados del trabajo y el capítulo 4 a las conclusiones del mismo.

2. SPACE-TEMPORARY GRAZING MANAGEMENT IMPROVED PRODUCTIVE RESULTS IN COW-CALF CAMPOS GRASSLAND ECOSYSTEMS

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2.1 SUMMARY

Campos grassland cow-calf systems sustainability have been compromised by low productive results for the last decades in Río de la Plata, associated to lack of energy balance management and overgrazing. The aim of this study was to quantify and explain the relationship between grazing management models, cow-calf practices adoption and level of forage height (FH) and allowance (FA), cows live weight (LW), body condition score (BCS), forage growth (FG) and intake (DMI), metabolic hormones response (IGF-1, Insulin and Leptin) and reproductive and productive results during two breeding seasons (BS1: 2017-18 and BS2: 2018-19) in three family farm system (FS). The FS were selected as case study for their coinnovation trajectories (0 to 5 years) and characterized by structure, grazing management and an indicator of level of adoption of cow-calf practices was calculated (IPC, score 1-100). The FS defined as space-temporal grazing manager (STM), 18 % of pasture improvements (PI), and 85 IPC with 5 years of coinnovation trajectory, resulted in 6.2 ± 1.5 cm, 5.3 ± 1.0 kgMS $kgLW^{-1}$, 4.9 ± 0.3 (scale 1-8) in FH, FA and BCS respectively, 47 % more DMI ($P < 0.05$) and 79 % (72 ug/mL) IGF-1 at calving, associated to 100 % pregnancy rate, 213 kilograms (kg) of weaned calf per breeding cow and 132 kg of beef meat per hectare. STM produced 90 % and 58 % more kg of weaned calf per breeding cow and beef meat per hectare compared to TNM, explained mainly by an overall higher

nutritional and anabolic status directed toward calf production. Also despite a reduction in 35 % of FH and FA during BS2, reproductive and productive results remained in similar higher levels, which could probably be explained by a process known as metabolic memory and adaptative management. The information generated in this study evidenced the complexity of the associations of processes that explain FS results, therefore the need for an adaptative, participative systemic approach for FS ecological intensification redesign; with spatial-temporary grazing management as a central proccess technology, that without modifying resources, improved productive results, sustainability and alleviate climate uncertainty at cow-calf FS on Campos grassland.
Key words: cow-calf systems, campos grassland, grazing management

2.2 INTRODUCTION

Beef farming grazing ecosystems at Campos grassland (Allen et al., 2011) are the main economic and social activity of agriculture and occupy 700.000 kms^2 in South America, which represent an important source of biodiversity, with more than 4000 species grasses of cycle C3 and C4 (Soriano, 1992), and ecosystem services for the region (Paruelo et al., 2010; Carvalho et al., 2009). In Uruguay, Campos grassland constitutes 90 % of the forage resource used in 12.4 million hectares destined for beef production (DIEA, 2014) with 51 % of the area oriented to calf production and 63 % (15.675) (DIEA, 2014) of farms defined as family farm systems (FS) (Piñeiro, 1985). The FS in Campos Río de la Plata and Uruguay have limited sustainability; the average beef production has been 70 kilograms of meat ha^{-1} $year^{-1}$ and the calving rate 64 % during the last 10 years (DIEA, 2014). This limited production levels had been debated regionally and could be explained mainly by high stocking rate and absence of grazing and beef cow management (Carriquiry et al., 2012; Carvalho et al., 2011; Soca et al., 2007).

Campos grassland is dominated by C4 grasses species, which are subject to seasonal variability of forage production due to temperature limitations during winter and soil hydric balance during spring, summer and autumn (Berretta et al., 2000). This variability in forage production and absence of forage allowance (FA) control and beef cow management practices, also contribute to explain reduced levels of forage biomass (Maraschin et al., 2001), cows forage intake, negative energy balance (BEN), resulting in low body condition score (BCS) at calving, long anestrus postpartum, limited probability of pregnancy and calf live weight (LW) at weaning (Meikle et al., 2018; Soca y Orcasberro, 1992; Short et al., 1990), meat production and economic net income of FS (Do Carmo et al., 2018; Soca et al., 2007).

Long term experiments by Grazing Ecology group of Facultad de Agronomía (Universidad de la República, Uruguay) demonstrated that an improvement of FA from 2.5 to 5 kgDM $kgLW^{-1}$ and its seasonal variation allows to improve forage production, energy intake and efficiency of conversion of grassland to meat production (Do Carmo et al., 2018; Claramunt et al., 2018; Do Carmo et al., 2016). In addition to FA adjustment, control of moment and duration of mating, application of temporary weaning, flushing and definitively weaning at early cow gestation (during end of summer) contribute to improve redistribution of energy and nutrient partition for calf production (Soca et al., 2013bc).

Improvement of FA is associated with positive energy balance and increase in IGF-1, insulin and leptin concentration (Claramunt et al., 2018; Mapfumo et al., 2017; Laporta et al., 2013; Meikle et al., 2013; Soca et al., 2013a; Astessiano et al., 2012) which promote anabolic processes (Hess et al., 2005) by enzymatic activity regulation of the anabolic routes for production. There is a positive relationship between nutritional status and its trajectory, levels of anabolic hormones and animal ability to adapt resources acquisition and metabolism to be more efficient and therefore more resilient in periods of shortage of forage (Friggens et al., 2017; Blanc et al., 2006; Chilliard et al., 1998).

At commercial FS level, Paparamborda (2017) demonstrated that meat production per hectare was 30 % higher ($P < 0.05$) at FS defined as Spatial-Temporal Managers (STM) compared to Traditional Non Managers (TNM). In addition, the absence of cow-calf practices as breeding season control, BCS and suckling management also result in an inefficient cow energy flow distribution for calf production (Do Carmo et al., 2016; Soca et al., 2013bc). The 41 % of the FS still practiced continuous mating and only 58 % practiced BCS classification to orientate grazing management decisions and 35 % applied suckling restriction management, showing a low adoption of sustainable intensification technologies practices by FS (Paparamborda, 2017; Gómez-Miller y Saravia, 2016; Oyhantçabal, 2003; Pereira, 2003).

This problem led to a need for a systemic approach that articulates analytic and field research to improve production, income and sustainability at FS (Coquil et al., 2018; Briske et al., 2011), while preserving the triggered ecosystem of Campos grassland (Carvalho et al., 2008). The failure of uptake of practices by farmers has been attributed to a component-based, rather than a systems-based approach to extension (Dogliotti et al., 2014) and to a failure of the dominant transfer of technology approach to promote learning for innovation (Oyantçabal, 2003).

Co-innovation is a systemic participative approach that has proven to be a successful collective learning process between farmers and technical advisors mainly to improve farm production and sustainability (Dogliotti et al., 2014). The co-innovation approach (Rossing et al., 2010) was implemented in cow-calf systems in Uruguay (Albicette et al., 2017), technically based on grazing intensity management (Do Carmo et al., 2016; Soca y Orcasberro, 1992). After three years' implementation it resulted in an improvement of FA from 3.3 to 5.6 kgDM $kgLW^{-1}$, meat production from 99 to 122 kg ha^{-1} and kilograms of weaned calf per breeding cows from 107 to 140 (Ruggia et al., 2015).

Co innovation participative learning process focused on space-temporary management to ensamble the energy balance at cow-calf grazing ecosystem in the long term, can improve productivity and make possitive changes at FS (Albicette et al., 2017; Falconnier et al., 2017). However, FS information of how grazing intensity and beef cow management are related to quantified levels of variables that define grazing systems, in time and space, was not available. Nor the information about the process variables levels to explain the energy flow from grass to calf production on Campos grassland (Do Carmo et al., 2016). The quantification of the relationship between management and these forage and animal variables would contribute to re design sustainable FS on Campos grasslands.

The aim of this study was to quantify and explain the relationship between the FS grazing and cow-calf practices management and the resulting seasonal levels of forage height and allowance, cows LW, BCS, forage growth, intake, metabolic hormones response, and the production of kilograms of calves per cow and meat per surface during two consecutive years on Campos grassland.

Our hypothesis was that management of grazing intensity per paddock and season integrated with the adoption of cow-calf practices that control cow energy intake and balance during a trajectory in time, improve forage height and allowance, animal BCS, forage production, intake and anabolic hormones response and results of kilograms of calf per breeding cow and meat production per surface in higher levels that can contribute to improve FS sustainability and resilience on Campos grassland without increasing resources.

2.3 MATERIALS AND METHODS

2.3.1 Study area

The study was carried out at three FS taken as case study (Yin, 2013), based on Campos grassland located on Sierra del Este, East of Uruguay

(34°28′ S, 54°19′ W, Figure 1) during two consecutives breeding seasons (calving-lactation, mating and weaning period); BS1: September 2017-March 2018 and BS2: September 2018-April 2019.

Figure 1. Study area ubication in Sierra del Este, Uruguay (IGM, Uruguay).

Sierra del Este eco-zone occupies 2.63 million hectares, with an altitude that varies up to 500 m in hills disposition, and predominant soils of Brunosoles subeútricos-distrícos and litosoles, moderately superficial and rocky surface (Brazeiro et al., 2012).

Annual average precipitations vary between 1200 and 1400 mm and average temperature is 17.5 °C (Castaño et al., 2011). Due to proximity FS1 and FS2 were located within the same satelite quadrant for monthly effective rainfall precipitations (Figure 2) and available water at (Figure 3) estimations (INIA, GRAS).

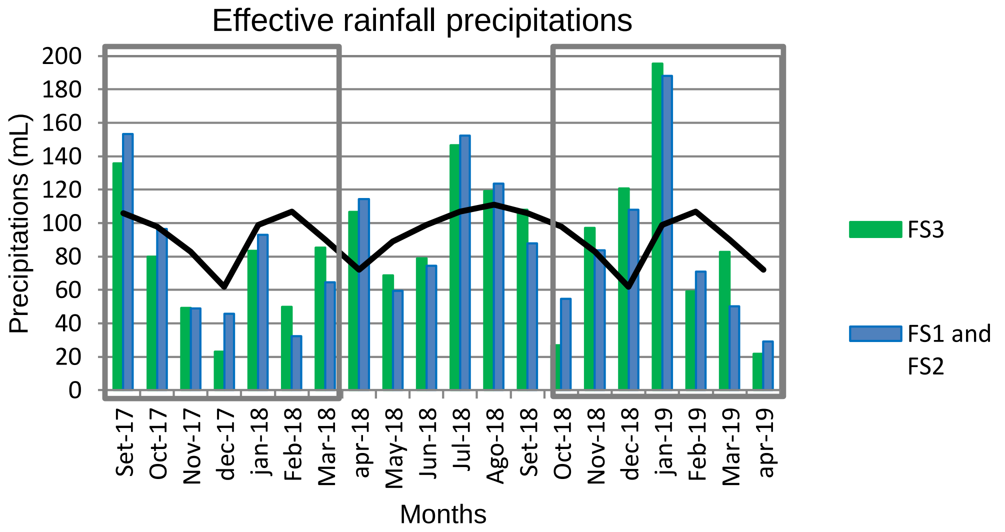

Figure 2. Effective monthly precipitations at Farm Systems (FS) sites during September 2017-April 2019 (in grey rectangles are enclosed the two periods of the study) and national average during last 30 years (INIA GRAS, 2020).

Evolution of precipitations was similar between FS (Figure 1) and shortage respect to the last 30 years' average contributed to explain soil available water reduction during November, December 2017, and February and October 2018 (Figure 2 and 3).

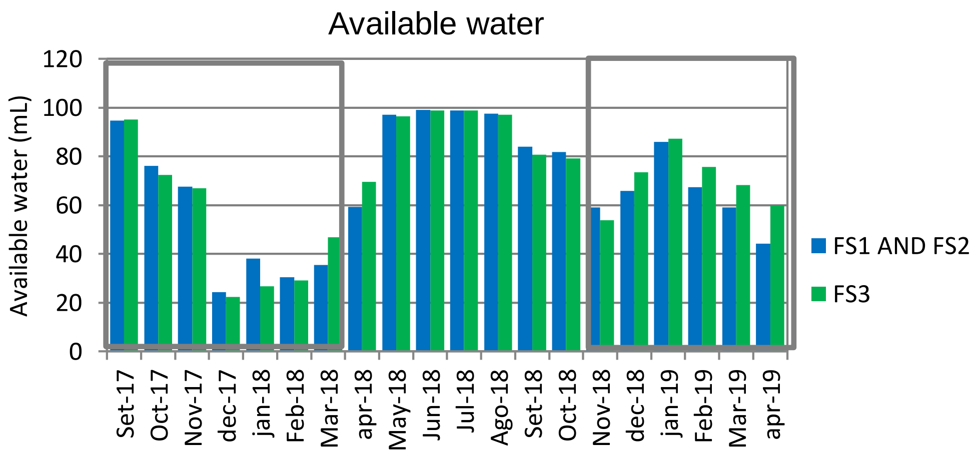

Figure 3. Soil available water at the Farm Systems (FS) sites during September 2017 to April 2019 (grey rectangles enclosed the two period of the study) (INIA, GRAS).

2.3.2 Selection of case study farms

The FS case study were selected based on a previous national survey that characterized 272 FS in Uruguay (Paparamborda, 2017), where 30 % were also beneficiaries of a national FS and Climate change government project (MGAP-BID) and a smaller group of 27 FS were beneficiaries of an ongoing co innovation regional Fontagro project that involved farmers, researchers and policy maker institutions which constituted the framework of this study (Figure 4).

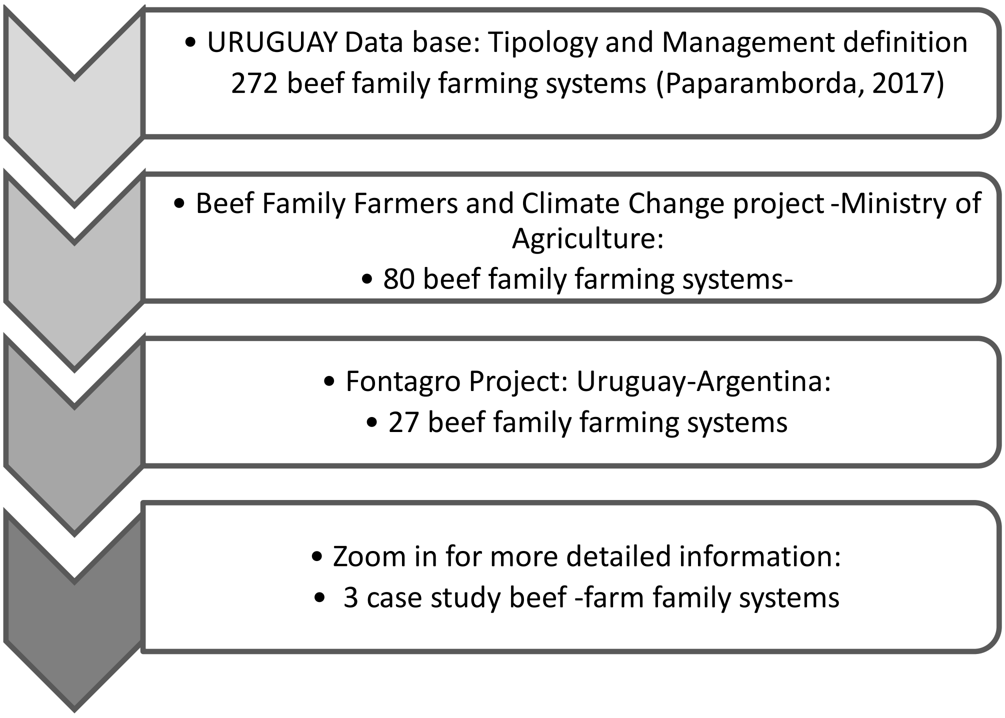

Figure 4. Context and source of selection of family farm systems case study.

The FS case study selection criteria were the trajectory in years of co innovation learning process (Dogliotti et al., 2014) between farmers and field advisors based on management redesign of the system to improve calf production at grazing cow-calf FS: FS1 had 0, FS2 recent (first year in co innovation project) and FS3 had 5 years of trajectory as beneficiary of previous co innovation projects (Albicette et al., 2017; Ruggia et al., 2015).

The FS taken as case study had also different previous reproductive and productive results, associated to 40, 61 and 91 percentage of weaning rate for FS1, FS2 and FS3 respectively during 2016-2017.

2.3.3 Farm systems structure and resources

Structure and resources of FS involved in production were assessed directly from farmers and/or project field advisor and included: farm area in hectares, percentage of area occupied by Campos grassland, effective grazing area, soil type (USDA, 1999), number of paddocks, percentage of total area occupied by pasture improvements, herd size (number of cows and yearlings), stocking rate (animal unit per hectare), sheep to cattle ratio, identification of management decision maker/s, living facility, residence at farm, off farm labour and land tenure (Aguerre et al., 2018; Modernel et al., 2018).

2.3.4 Grazing and cow-calf management models

A classification of FS as Traditional Non-Manager (TNM), Manager (M) and Space-Temporal Manager (STM) according to their grazing and beef cow management practices based on control of mating season, spatial-temporal paddocks utilization and stocking rate level (Paparamborda, 2017) was applied. Pattern of paddock utilization is an indicator of farmer grazing management planning, and varies from 0 to 4, where 0 is undefined paddock utilization and 4 an explicit definition of paddock per animal category in time (Paparamborda, 2017). In summary: 1) TNM defined a FS with continuous mating and/or no pattern of paddock utilization system; 2) M defined a FS with control of mating season and pattern of paddock utilization between 1 and 3; 3) STM defined a FS with control of mating season, a defined pattern of paddock utilization above 3 and stocking rate below 1.3 UG ha^{-1} (Paparamborda, 2017).

A scheme of seasonal grassland paddock utilization was constructed based on models proposed by Girard and Hubert (1999), and Duru and Hubert (2003) (Figure 5).

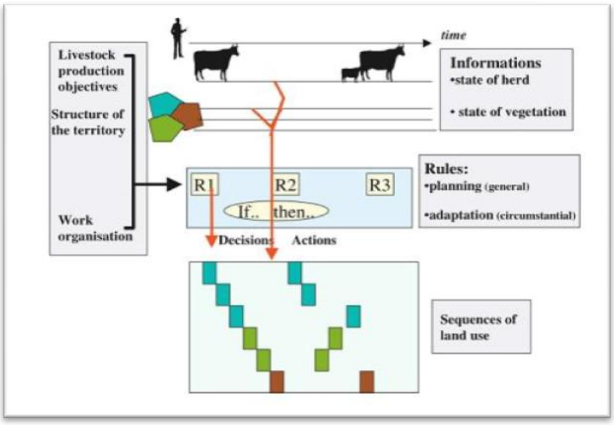

Figure 5. Conceptual model of farmer space and temporary grazing decisions criteria (Duru and Hubert, 2003).

Monthly paddock/s occupation of the breeding herd, with the species (bovine, ovine and equine), quantity and category of animals grazing together were registered during September 2017-April 2019. These monthly information was assessed from project field technical advisor and the criteria for paddock assignment from the farmer.

Also the proportion of pasture improvement (PI) utilization (PIU) was calculated for each month, as the amount of cows grazing in PI paddocks divided by total amount of cows in the herd. The PIU was only possible to be calculated for FS3.

An index of technological practices in cow-calf-systems (IPC, Paparamborda, 2017) was calculated as an indicator of level of adoption of practices to control cow energy balance flow. The IPC is a numeric indicator that varies from 0 to 100 where for each practice and level of adoption a numeric value is given with relative weight determined by experts, and are classified as: strategic, decision aid and tactic practices (Paparamborda, 2017).

2.3.5 Forage height and forage allowance

Forage height was measured in September, November, January and March during BS1, in June 2018, and in October, December and April during BS2 based in double sampling method (Do Carmo et al., 2020; Haydock and Shaw, 1975), 100 points of FH were measured in a transect of CG paddocks where the breeding cows were grazing, which included a total of two paddocks in FS1 and FS2 and four paddocks in FS3. Forage mass availability (kgDM ha^{-1}) was estimated taken a FH and forage mass relation reported for CG of 1 cm to 300 kilograms of DM (Do Carmo et al., 2015).

Forage allowance (kgDM $kgLW^{-1}$) was calculated as a ratio between forage mass available in DM kilograms (Do Carmo et al., 2015) per total kilograms of animals LW (Sollenberger, 2005).

2.3.6 Cow body condition scores and live weight

Body condition score (BCS) (visual scale 1–8, Vizcarra et al., 1986) and no fasting live weight (LW) of the same multiparous cows (n= 27 ± 2) were determined during BS1, June 2018, and BS2 (same dates as forage measurements).

Calves no fasted LW were registered in March 2018 and 2019 to estimate calves weaning weight for each FS fixed at 205 pospartum days (PPD).

2.3.7 Cows post-partum days estimation

During BS1 PPD were estimated based on national reported calves LW at birth of 37.8 and 39.8 kilogram for female and male respectively (Dañobeytia et al., 2015) and calf LW daily gain average calculated (based on the no fasted calves LW measured in November 2017 and March 2018), that resulted in 0.70, 0.76 and 0.94 kilograms per day for FS1, FS2 and FS3 respectively. The FS PPD and dispersion for BS1 are presented in Table 1.

Table 1. Average cow postpartum days at farm systems.

	PPD[2]	PPD	PPD	PPD
	September 2017	November 2017	January 2018	March 2018
FS[1]	Calving- Lactation[3]	Mating[4]	Mating	Weaning
FS1	34 ± 39	76 ± 39	129 ± 39[6]	173 ± 39
FS2	26 ± 42	81 ± 42	132 ± 42[6]	191 ± 42
FS3	-17 ± 14	38 ± 14	89 ± 14[5]	148 ± 14

[1]Family Farm System.

[2]Post-partum days as the estimation of the days after calving for the breeding herd.

[3]Period of calving and lactation superposition.

[4]Beginning of Mating Season.

[5]Post-partum days by the end of mating season at Family Farm System 3.

[6]Post-partum days by the middle of mating season in Family Farm System 1 and 2.

2.3.8 Metabolic hormones serum concentration

Multiparous cow serum metabolic hormones were determined by blood samples drawn from the coccygeal vessels during BS1: calving-lactation, middle and end of mating and calf weaning of the first year of study (September, Novemeber 2017 and January, March 2018). Blood samples were centrifuged at the farm for 20 minutes at 3500 rpm and two series of 1mL of serum per cow and per moment were identified, transported refrigerated at 4 °C and stored at -20 °C until laboratory analysis.

Serum samples of the same 12 cows per farm were assayed in the Laboratory of Endocrinology and Animal Metabolism, School of Veterinary, Universidad de la República of Uruguay to determinate serum concentration of Insulin growth factor I (IGF-1), Insulin and Leptin.

IGF-1 was determined using a immunoradiometric assay of a commercial kit (IGF1-RIACT Cis Bio International, GIF-SUR-YVETTE CEDEX, France). The kit contains two monoclonal antibodies against two different antigenic sites of IGF-I molecule, one is coated on the solid phase, the other radiolabeled with iodine 125. Samples are first treated with an acidic solution to strip the carrier protein which is then saturated with IGF-II to avoid the reassociation between IGF-I and the carrier protein. The sensitivity of the assay is 0.55 ng mL^{-1}. The intra-assay CVs for control 1 (48 ng mL^{-1}) and control 2 (390 ng mL^{-1}) were 9.8 % and 11.9 % respectively. The inter-assay CVs for the same controls were 13.3 % and 11.3 % respectively.

Insulin was determined using a immunoradiometric assay of a commercial kit (DIAsource Immuno Assays S.A, Nivelles, Belgium). The sensitivity of the assay was 1.06 µUI mL^{-1}. The intra-assay CVs for control 1 (17.3 µUI mL^{-1}) and control 2 (66.4 µUI mL^{-1}) were 2.34 % and 3.36 % respectively.

Leptin concentrations were determined by a liquid-phase radioimmunoassay (RIA) using a commercial Multi-Species Leptin kit (RIA kit, Millipore, Cat XL-85K) previously reported in bovines (Pinotti and Rosi 2006). The RIA had a sensitivity of 1.68 ng ml^{-1}. The intra-assay coefficients of variation for low (13.9 ng ml^{-1}) and medium (44.5 ng ml^{-1}) controls were 12.6 % and 7.7 % respectively. The inter-assay coefficients of variation for low and medium controls were 17.2 % and 7.8 % respectively.

2.3.9 Forage growth

Forage growth (FG) was estimated from September 2017 to April 2019 by satellite sensors (Sentinel 2) from normalized difference vegetation index (NDVI), were associated with aboveground net primary production (ANPP) (Baeza et al., 2010; Grigera et al., 2007) and was assumed data on radiation use efficiency derived from regional literature for each forage resource (Druille et al., 2019).

Pure pixels were considered to estimate FG per paddock and month (Paruelo, 2008). The estimated FG per date resulted from the FS paddocks average poderated according to the area of each paddock. FG of PI was estimated only for FS3.

2.3.10 Forage and energy intake estimation

Forage intake was estimated by CSIRO (1990) model where the potential energy intake (EI) depends on the animal size and the relationship with animal LW, and the relative intake integrates the limitations related to forage quantity and quality (Mieres, 2004). The estimated EI was calculated based on the cows LW and the forage availability measured for each period evaluated during BS1, June 2018 and BS2.

The normal weight of each cow was estimated as:

$$\text{Normal weight (N)} = A – (A – B) \exp^{(–k\ T\ A^{–0,27})};$$

where, A= mature weight (kg), B= weight at birth (kg), T = age of animal (months), k = 0.35 for bovines.

The potential intake for non lactating animals was estimated as:

$$\text{Non Lactating Potential Intake (I, kg MS/día)} = j\ A\ Z\ (1{,}7 – Z);$$

where, j = 0,025 for cows, Z (relative weight) = N/A

and for lactating animals;

$$\text{Lactating Potential Intake (I, kg MS/día)} = j\ A\ Z\ (1{,}7 – Z) \times m;$$

$m = 1.0 + a\ T^{1.7} \exp^{(-0.021T)}$;

Where a = 0.0013 beef cows and T = time from calving in days

The relative intake (F), integrates the intake rate (E) and the grazing time (T)

$$F = E \times T = [1 – \exp(-aH)] \times [1 – b \exp(-kH^2)];$$

Where F = relative availability factor, E = intake rate (gr/day), T = grazing time (min/day), a = 0,8 for bovines, H = forage availability, b = 0,6, k =0,5 for bovines.

$$R = [1- H (0.8 – D) + 0.17 G];$$

where R = pasture quality correction factor, H = 1 for native pasture y G = proportion of legumes in pasture.

Therefore, the metabolizable energy intake (MEI) per cow and day was estimated as:

MEI (Mcal ME/cow/day) = I * F * R * 1.96

2.3.11 Pregnancy diagnosis

Pregnancy diagnosis by ultrasonography was performed on April 19th, and April 27th of 2018 and 2019 respectively, considering a minimum of 30 days after bull withdrawal in every farm. A linear array real time ultrasound scanner with 7.5 MHz rectal transducers was used (Imago, France). Criteria for pregnancy diagnosis was identification of uterus with an embryo, observed as an ecogenic picture sharply demarcated in an unecogenic (black) area, and/or the observation of heart beat (sensitivity of 94.8 %, specificity of 95.3 %, positive predictive value 97.7 % and negative predictive value 89.8 %; Taverne et al., 1985).

2.3.12 Calf and beef meat production

Kilograms of weaned calf per breeding cow were calculated, with calves LW registered in March of 2018 and April 2019 and adjusted at 205 PPD and the previous weaning rate.

Beef meat production per year and hectare (Alvarez y Falcao, 2011) was provided by the project and calculated as:

Kilograms of meat per hectare and year (Kg ha-1 year-1) = (kgs sold + kgs outcome (other) – income Kgs +/- stock difference)/Effective Grazing Area

2.3.13 Statistical analysis

All data were analyzed using procedures of the SAS Systems program (SAS Institute Inc., Cary, NC, USA). The effect of FS on cow BCS, cow and calf LW, and serum concentrations of IGF-1, insulin and leptin considered the cow or calf in each date as the experimental units, while the experimental unit for forage height, herbage allowance and herbage growth was the FS. Thus, the FS effect on herbage growth, herbage height and herbage allowance was analyzed using general linear models considering the date as a replica. The effect of FS, date and their interactions on BCS, LW, and serum concentrations of IGF-1, insulin and leptin were analyzed via mixed models with date as the repeated-measure. The Kenward–Rogers procedure was used to adjust the denominator degrees of freedom and covariance matrixes were selected on the basis of the lowest Akaike information criterion. The effect of FS on proportion of pregnant cows was fit based in generalized linear model assuming a binomial distribution, and logit as the link function. The data were expressed as least square means ± standard error. Least square means were compared using the Tukey-Kramer test, and differences were considered to be statistically significant at $P < 0.05$ and between $P > 0.05$ and $P < 0.1$ a trend.

The Pearson correlation coefficient among variables was estimated and significant correlations was considered at $P < 0.05$. Furthermore, regression models were conducted to study the associations among: 1) herbage growth, soil moisture, growth seasonal periods (spring-summer and autumn-winter) and their interaction, and 2) IGF-1 concentration with calf LW on November, 2017, the difference in BCS between November and September 2017, the initial IGF1 concentration in September 2017 and their interactions. Multiple regression analysis via the Stepwise method was conducted to select variables associated with pregnancy rates and the first calf LW registered in November 2017 at calving-lactation. A forward-backward approach with a $P < 0.25$ for variables selection was used. The selected variables and their interactions were tested in a generalized linear model for proportion of pregnant cows and general lineal model for calf LW in November. Non-significant variables ($P<0.05$) were removed in the regression and Stepwise models.

2.4 RESULTS

2.4.1 Farm systems structure

Calf and meat production were mainly based on Campos grassland, between 82 and 96 % of the farm area was under Campos grassland and farms varied from 82 to 231 ha (Table 2). The FS with highest stocking rate and sheep/cattle relationship rate was the smallest in total area with minor area of PI (Table 2).

Table 2. Farm systems structure.

Indicator	FS1	FS2	FS3
Farm size (ha)	82	222	231
Campos grassland (%)[1]	96	96	82
Effective Grazing Area (ha)[2]	74	176	210
Soil type[3]	Haplic and typical Subeutric Brunosols	Haplic and typical Subeutric Brunosols	Luvic Sub-aquic Brunosols
Paddocks (n)	6	10	19
Total cows heads in herd	58	136	138
Pasture Improvement (%)[4]	4	4	18
Stocking Rate (AU/ha)[5]	1.2	0.99	0.92
Sheep/Cattle Rate[6]	0.7	0.9	0.3

[1]Percentage of total farm area.

[2]Area that effectively can be grazed by the animals, is the area used for productive indicators per surface.

[3]Soil classification system (USDA, 1999).

[4] Area of pasture improvement in relation total area expressed as a percentage includes improvements of natural grassland and artificial pastures.

[5]Animal unit, used in the region to convert different animal domestic species, ages and sex into a comparable unit, by applying a correction factor (cow= 1, bull= 1.2, heifer less than 2 years= 0.7, calf= 0.4), per total surface (Allen et al., 2011).

[6]Relation of sheep/cattle in heads.

Land was owned by the family at the three farms; but only FS3 lived at farm and had no off farm labour (Table 3).

Table 3. Farm systems resources.

Farm characteristic	FS 1	FS 2	FS 3
Householders/decision makers[1]	2, MS	2, B	2, C
Living Facility[2]	No, NE	Yes	Yes
Residence at Farm[3]	No,15	No,10	Yes
Off farm labour [4]	Yes, C	Yes, M	No
Land tenure	Yes	Yes	Yes
Co innovation trajectory (years) [5]	0, NB	1, RB	5, BB

[1] Number of persons, M=Mother, S=Son, B=Brother, C=Couple.

[2] Housing at farm, NE=no electric power during the first year of study.

[3] Yes/No, distance to farm in kilometers.

[4] Work outside the farm with external income, C=Carpenter, M= Agriculture machinery.

[5] Total years as beneficiaries of co innovation projects, NB=no beneficiary, RB=recent beneficiary, BB= previously beneficiary.

2.4.2 Grazing management

Pattern of forage utilization was different between FS (Figure 6a and 6b). The FS1 and FS2 assigned same Campos grassland paddocks to beef cows herd during most of the study, except FS2 during October 2017 (calving-lactation) and April 2019 (weaning), and resulted classified as poor to non space-time grazing management (Figure 6a).

However, FS3 assigned 3 to 6 different paddocks between CG and PI. The criteria for paddock assignment were cows BCS, physiological status, age, and paddocks FH with the objective of maintaining high cows BCS (Figure 6b). FS3 combining strategical, general planification and circunstancial adaptative decisions resulted in paddocks with 1 and up to 65 cows ocupation. This FS also managed PI strategically for mated heifers and primiparous cows, and low BCS multiparous cows, during calving-lactation, mating and weaning periods, with an average of 36 and 40 % of total herd assigned to PI during BS1 and BS2 respectively (Figure 6a and 6b).

FS1	CALVING-LACTATION		MATING			WEANING	END AUTUMN	CALVING-LACTATION		MATING			WEANING	
Paddocks ID[1]	Sep 2017	Oct2017	Nov2017	Dec2017	Jan2018	Mar 2018	Jun 2018	Sep2018	Oct2018	Nov2018	Dec2018	Jan2019	Feb 2019	Apr 2019
1 CG														
2CG			48											
3CG														
4CG														
5CG	10 (H)				10 (H)	10 (H)	10 (H)	10 (H)	10 (H)		10 (H)			10 (H)
6CG	48				48	48	47	47	47		47			47

FS2	CALVING-LACTATION		MATING			WEANING	END AUTUMN	CALVING-LACTATION		MATING			WEANING	
Paddock ID	Sep-2017	Oct-2017	Nov-2017	Dec-2017	Jan-2018	Mar-2018	Jun-2018	Sep-2018	Oct-2018	Nov-2018	Dec-2018	Jan-2019	Mar-2019	Apr-2019
1CG							42		51H	58 H		58H		
2CG														
3CG	51		25	25	37	70	42	51		25			58	42 H
4CG			50	50	41	26	32	58 Y	50			41	26	
5CG														12
6CG														17

Figure 6a. Spatial and temporal grazing patterns at FS1 and FS2. Light green shadowed areas represent Campos grassland paddocks occupied by multiparous beef cows and mated heifers (H) with the quantity in number of heads as available (gray shadowed areas correspond to mating months) from September 2017 to April 2019.

FS 3	CALVING-LACTATION		MATING		WEANING	END AUTUMN	CALVING-LACTATION	MATING			WEANING	
Paddock ID	Sep-2017	Oct-2017	Nov-Dec 2017	Jan-2018	Mar-2018	May-Jun 2018	Sep-Oct 2018	Nov 2018	Dec 2018	Jan 2019	Mar 2019	Apr 2019
La llanada CG		5	29		15	11		13	32	2+4(H)		15
Las Casas CG		38		20+ 1H			10	26		8		7
Las Casas PI							8			2		
Acosta CG	5	8	27 (H)	26(H)	1	14	7	11	30	26 (H)	24	
LeonardoCG	16	16				15	10		25 (H)		30(H)	25 (H)
FondoCG	30	1	26	32	30(1)	42	20	19		31 (P)	70	65
Maku PI	27(1)			27(1			30 H	30H				
LasChilcas CG		2		9			2					
CerroasperoCG			31Y		26 Y	25(Y)	25Y		31Y	25 Y	47	2 F
Baño CG		5 F		13			7	8	13			25
Pradera vieja PI	27 (H)	27(H)					11	12				8
Pradera 11 PI				8	51		24 (1)					
Pradera 12 PI		27(1)	27 (1)		26						25 H	
Maku NuevoPI				2		6						
Los sauces CG						27 (1)						
La costa PI								11	31	28(Cy)		5 F
Festuca PI									26	30 (Cy)		
PI usage[2]	0.39	0.39	0.2	0.27	0.56	0.04	0.53	0.38	0.41	0.43	0.2	0.06

[1] paddock denomination by the farmer and resource: CG, Campos Grassland; PI, Pasture Improvement

[2] Pasture Improvement (PI) Usage as proportion of total cows and heifers grazing on PI per month.

Figure 6b. Spatial and temporal grazing pattern at FS3. Light green shadowed areas represent Campos grassland and darker green areas represent PI paddocks occupied by multiparous and primiparous (1) beef cows and mated heifers (H) and the physiological status (P: pregnant, Cy: cycling) and quantity as available at FS (gray shadowed areas correspond to mating months) from September 2017 to April 2019.

2.4.3 <u>Management practices in cow-calf-systems (IPC)</u>

The FS3 adopted main strategic practices as season control of mating and calving, cow BCS classification, pregnancy and ovarian activity diagnosis and suckling control practices, also autumn forage deferement and PI assignment to heifers which resulted in an overall higher IPC compared to FS1 and FS2 (Table 4). At beginning of this work FS2 was in the process of reducing mating season duration which was associated to IPC difference between BS1 and BS2 (Table 4).

Table 4. Index of management practices in cow-calf systems (IPC)

FS Practices: What do FS do?	Level of adoption: How do FS do it?	Adjusted numeric value	FS1	FS2	FS3
Control of Breeding Season	Two seasons[1]	5	-	5 [1]	-
	Summer (3 months)	10	10	10[2]	10
Management of cows	Two lots according to BCS or 2nd breeding	15	-	-	15
Management of Heifers	Allow heifers to best forage	7.5	7.5	-	-
	Allow heifers to forage improvements	10	-	-	10
Autumn deferment of Forage	Practiced	10	-	0 [1]/10 [2]	10
Month calves weaning	March	15	15 [2]	-	15
	May	7.5	7.5 [1]	7.5	-
Body Condition Score Classification	Without scale for forage allowance purpose	7.5	-	-	7.5
	Without scale for other purpose	0	0	0	-
Ovarian Activity diagnosis	For other purpose	2.5	-	2.5	-
	For suckling control decisions	5	5	-	5
Pregnancy diagnosis	To more than 60 % of the herd	5	5	5	5
Bull Reproductive Check	Check by the farmer	2.5	-	-	2.5
Suckling control Management	Only temporary weaning without flushing	5	5	-	5
Total IPC[3]			40[1]/47.5[2]	20[1] / 35[2]	85

[1]Farm practices in 2017-2018, Farm 2 changed from continuous to seasonal mating.

[2]Farm practices in 2018-2019, Farm 1 weaned on February 2019.

[3] Index of cow-calf practices adoption in a scale 0-100 (Paparamborda, 2017).

The FS3 resulted in the highest IPC which was related to a high level of cow-calf practices adoption, also comparing herd reproductive management in more detail FS3 had an earlier mating period that began 10 and 30 days earlier than FS1 and FS2 respectively and a differential mating date for heifers of 12 days earlier than multiparous cows. While FS3 decided to shorten the mating period for BS1 due to already high early pregnancy rate (88 %) at ovarian activity diagnosis (OAD) (Table 5).

On suckling control, the FS1 and FS3 practiced temporal weaning previous to mating during both BS, while FS2 incorporated this practice during BS2 (Table 5), while FS3 definitive weaning for primiparous cows was practiced earlier during BS2. On supplementation, FS3 supplemented the female calves with corn during almost all first winter season, resulting in a supplementation FS level of 10.5 kg per hectare and year (Table 5). The FS3 rearing nutritional management resulted in a difference in LW of heifers at mating of 112 and 124 more kilograms compared to FS1 and FS2 respectively, all at 24 months old. The FS3 was the only FS to practice flushing to heifers and primiparous cows based on PI (Table 5).

Table 5. Reproductive management at Farm Systems.

BS1[1]	FS1[3]	FS2[3]	FS3[3]
FS (age-LW)[4]	24-285	24-273	24-397
Mating C[5]	1 November-30 January	20 November-10 March	21 October-31 January
Mating H[6]	1 November-30 January	20 November-10 March	9 October-31 January
OAD[7]	..	..	10 January (88% pregnant)
Def. Weaning[8]	14 June	8-May	28 February
Temp. Weaning[9]	Yes	No	Yes (26 November)
Suplementation[10]	No	Calves (F) 10 days in winter (1.6 kg/day)	Calves (F) 90 days in winter (1 kg/day)
Flushing[11]	No	No	Pasture Improvement (P)
BS2[2]			
Mating C[5]	1 November-30 January	20 November-20 February	1 November-10 February
Mating H[6]	1 November-30 January	20 October-20 February	20 October-10 February
OAD[7]	..	..	28 December (65% pregnant)
Weaning[8]	15 February	11 May (male) /June (female)	12 March (18 February primiparous)
Temp. Weaning[9]	Yes	Yes (10 - 20 November)	Yes (November)
Suplementation[10]	No	Calves 5 days in winter (0.3kg/ha/year)	Calves 60 days in winter (10.5 kg/ha/year)
Flushing[11]	No	No	Pasture Improvement (H, P)

[1] Breeding Season1, period including calving, lactation, mating and weaning (September 2017 toMarch 2018).
[2]Breeding Season2, period including calving, lactation, mating and weaning (September 2018 to April2019).
[3]Family Farm System defined according to area, living, income and labor source (Piñeiro, 1985)
[4]First Service of Heifers: age in months and the live weight in kilograms of heifers at first service.
[5]Multiparous cows mating period with date of enter and withdrawal of bulls.
[6]Heifers mating period with date of enter and withdrawal of bulls.
[7] Ovarian Activity Diagnosis by ultrasonography to monitor the reproductive phisiological status during mating that classifies pregnant, cycling, superficial and deep anestrous cows (Quintans et al., 2010).
[8] Definitive weaning: date of definitive separation of calf from cow and end of lactation.
[9] Temporary Weaning, calf suckling restriction practice by the application of a nose plate for 10 days.
[10]Management practice of administrating an energetic concentrate supply (usually corn or rice bran) to a forage base diet for a period of time with the goal to increase animal energy intake, a rate of total kilograms of grains per hectare and year utilized per FS can be used to compare levels of suplementation (Kanter et al., 2016).
[11]Management practice of providing high quality feed to the female prior to the start of breeding proven to increase reproductive performance. P: primiparous cow, H: heifers.

Overall FS1 management definition (Paparamborda, 2017) was traditional no grazing manager (TNM) with a low-medium level of cow-calf practices adoption (Table 7). The FS2 was defined as TNM for BS1, switching to temporal manager (TM) for BS2 due to transition to seasonal mating control, with low practice adoption level. And FS3 was defined as STM with a high level jerarquized practices adoption (Table 6).

Table 6. Grazing management and practice adoption level definition of farm systems.

FS	Trajectory in participative learning process [1]	Grazing Management[2]	Practice Adoption (IPC/Level)[3]
FS1	0	Traditional	40[4]/47.5[5] MIDDLE
FS2	1	Non Manager[1]/Time Manager[2]	20[4]/35[5] LOW
FS3	5	Spatial and temporal Manager	85 HIGH

[1] Number of years in coinnovation farmer-advisor learning process on cow-calf family farm systems

[2] Definition of farmer according to space-temporal grazing management based on the control of mating season, the paddocks utilization and the stocking rate (Paparamborda, 2017)

[3] Index of cow-calf practice adoption (Paparamborda, 2017)

[4]Result for breeding season 2017-2018

[5]Result for breeding season 2018-2019

2.4.4 Productive and reproductive results at farm systems

During both BS beef meat productions per hectare was 58 % higher in FS3 than in FS1 and FS2 (Table 7). Kilograms of calf per breeding cow were 83 % superior in FS3. Pregnacy rate was 29 and 12 % higher in FS3 (100 %) compared to FS1 and FS2 respectively (Table 7).

Table 7. Farm systems reproductive and productive results.

BS[1]	Pregnancy Rate[3](%)	Weaned calf/ breeding cow (kg)[2]	Beef production kgs/ha[4]
BS1			
FS1[5]	71	106.2	68.0
FS2	88	105.8	90.9
FS3	100	194.8	133.7
BS2			
FS1	92	110.9	ND
FS2	78	129.3	76.9
FS3	100	217.6	131.3

[1] Breeding Season, considered from calving to weaning or September to March-April, BS1 was 2017-2018 and BS2 was 2018-2019 period.
[2] Kilograms of weaned calf per breeding cow fixed at 205 post-partum days for comparison between FS.
[3] Percentage of cows and heifers pregnant at the ultrasonography in April 2018 for BS1 and 2019 for BS2.
[4]Total kilograms of beef meat produced in the system in one year and divided per the effective grazing area of the FS in hectares.
[5]Family Farm System defined according to area, living, income and labor source (Piñeiro, 1985).

The FS calves LW daily gain was 0.71; 0.74 and 0.94 kilograms per day for FS1, FS2 and FS3 respectively during BS1.

2.4.5 Forage height and body condition score at FS

Forage height and cow body condition score were affected by FS ($P < 0.05$) (Table 8). During BS1 the FH, FA, BCS and LW were 4.2 cm, 3 kgMS/kgLW, 1 point (1-8 scale, Vizcarra et al., 1996) and 107 kilograms superior ($P < 0.05$) respectively in FS3 than in FS1 and FS 2 (Table 8). However, despite a 35 % reduction of FH ($P < 0.05$) during BS2 the differences in BCS among FS were maintained (Table 8).

Table 8. Forage height and allowance, cow body condition score and live weight from calving to weaning during breeding seasons BS1 and BS2 (least square means and standard deviation).

BS	FH[2] (cms)	FA[3] (kgs DM/ kgs LW)	Cows BSC[4] (1-8)	Cows LW[5] (Kgs)
BS1				
FS1[1]	3.4 ± 1.2a	3.0 ± 0.5a	4.0 ± 0.5a	404 ± 42a
FS2	3.3 ± 1.0a	2.6 ± 0.5a	3.9 ± 0.5a	403 ± 44a
FS3	7.5 ± 0.6b	6.1 ± 0.1b	4.9 ± 0.5b	512 ± 39b
BS2				
FS1	3.2 ± 0.2a	2.6 ± 0.2a	4.2 ± 0.5a	404 ± 35a
FS2	5.0 ± 2.8b	4.8 ± 3.5b	4.2 ± 0.5a	440 ± 37a
FS3	5.0 ± 1.1b	4.4 ± 0.8b	4.9 ± 0.5b	539 ± 33b

1 Family Farm System defined according to area, living, income and labor source (Piñeiro, 1985) and year (2017-2019)

2 Forage height as the average of 100 measurements per paddock (Do Carmo et al. 2020).

3 Forage Allowance as the quotient between kilograms of dry matter (DM) and kilogram of animal live weight (LW).

4 Cows Body Condition Score, indicator of body fat reserve in a scale from 1-8 (Vizcarra et al. 1986).

5 Cows unfastened live weight in kilograms.

Different letters within columns when statistically different (P < 0.05).

During the study FH at FS3 resulted numerically higher than FS1 and FS2 (Figure 7), however it was different from both FS during BS1 (P < 0.05), but only different from FS1 during BS2 (P < 0.05) since FS2 increased 2.8 cm the FH while FS3 decreased in similar magnitude (Figure 7).

During September 2017 to January 2018 (also growth period) the FH at FS3 scale up to levels of 8 cm, while FS1 and FS2 resulted in levels of 4 cm with no major changes registered (Figure 7). During March to October of 2018 (also dormant period) a reduction of FH in levels of 4 cm was registered at FS3, with levels down to 2 cm resulted for FS1 and FS2 (Figure 7). However, FS3 registered a progressive increment of FH toward April 2019 (Figure 7).

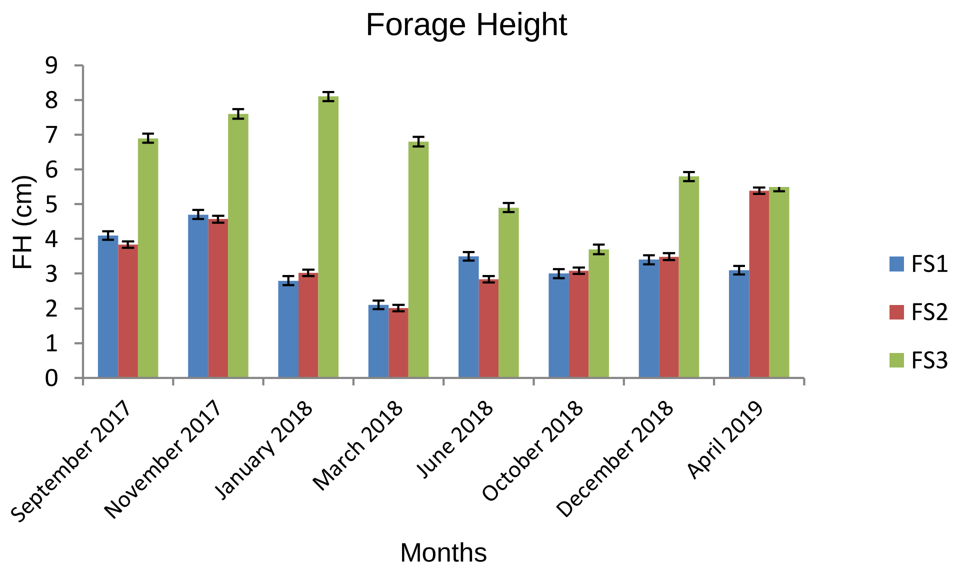

Figure 7. Forage Height (FH) evolution (least square means and standard deviation) at Farm Systems (FS) from September 2017 to April 2019.

Along the study FA at FS3 was numerically higher and reflected a similar evolution than the reported for FH at the FS (Figure 8).

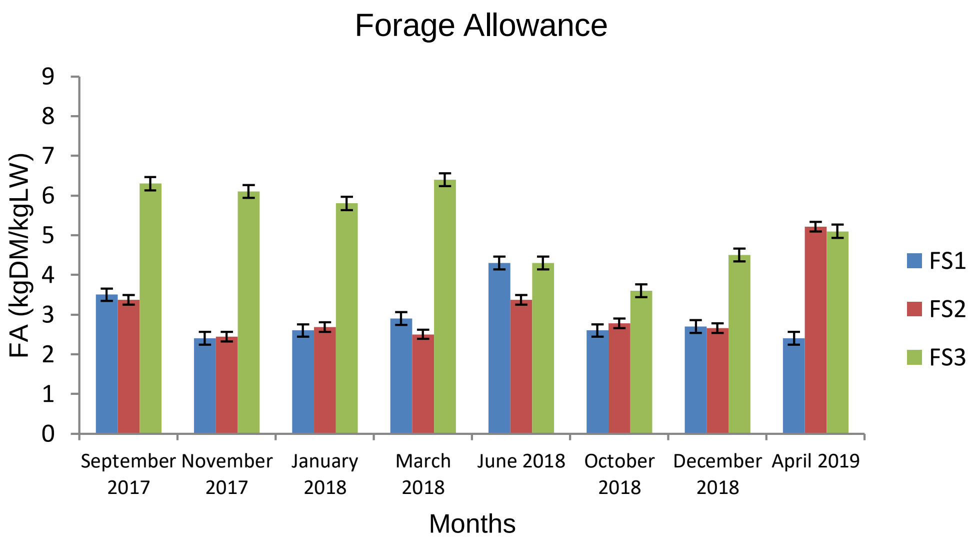

Figure 8. Forage allowance (FA) evolution (least square means and standard deviation) at Farm Systems (FS) from September 2017 to April 2019.

The BCS and LW were affected by FS and date interaction ($P < 0.05$). At FS3 the BCS resulted higher ($P < 0.05$) and in levels of 5 points in scale (Vizcarra et al., 1986) during both BS, while at FS1 and FS2 resulted in levels of 4 points in scale (Vizcarra et al., 1986) with 0.5 variation (Figure 9 and 10).

In FS and date interaction we founded two significantly higher registers of BCS at FS3 ($P < 0.05$), by 1.4 points on September 2017 (spring-calving) and 1.0 on June 2018 (end autumn) (Figure 9). Also BCS was inversely associated to increment of non-pregnant cows ($P < 0.05$) at FS.

The LW resulted in a similar pattern than the reported for BCS evolution (Figure 10).

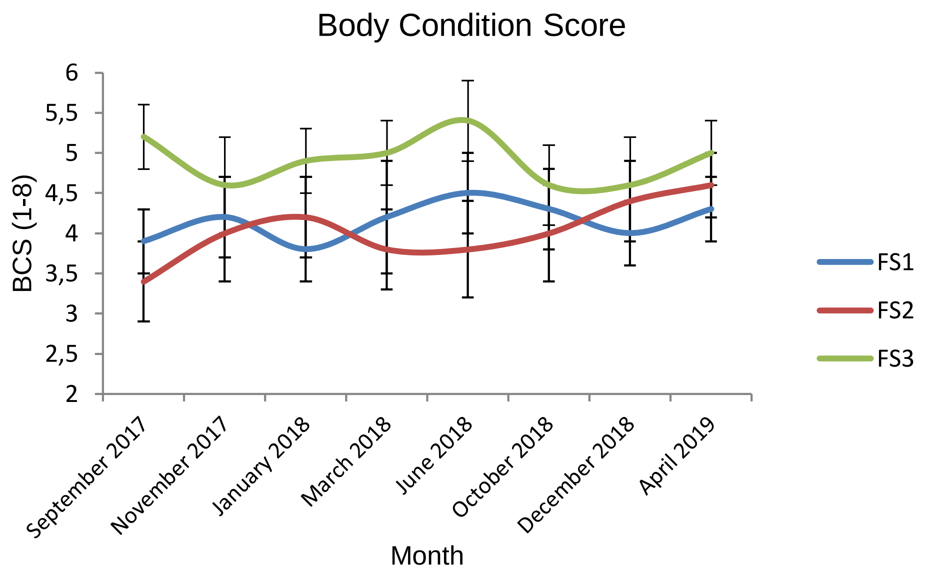

Figure 9. Body condition score (BCS) evolution (least square means and standard deviation) of multiparous cows at Farm System (FS) from September 2017 to April 2019.

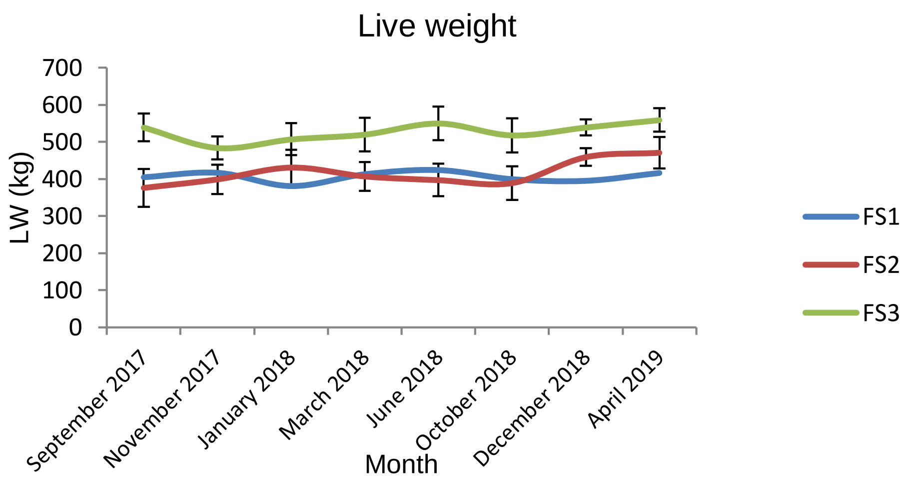

Figure 10. Live weight (LW) evolution (least square means and standard deviation) of multiparous cow at Farm Systems (FS) from September 2017 to April 2019.

2.4.6 Processes at farm systems: forage growth, cow energy intake and metabolic hormone concetration

2.4.6.1 Forage growth

Campos grassland forage growth (FG) was higher in FS1 ($P < 0.05$), with levels of 200 to 400 more kilograms of DM production per month during growth periods (September-March) and compared to FS3 (Figure 11). The FS3 PI production during Spring growth period resulted in levels above 1000 kilograms of DM per hectare and month (Figure 10), showing a higher value (1477 kilograms of DM) and also earlier forage production (August) registered during BS2 (Figure 12).

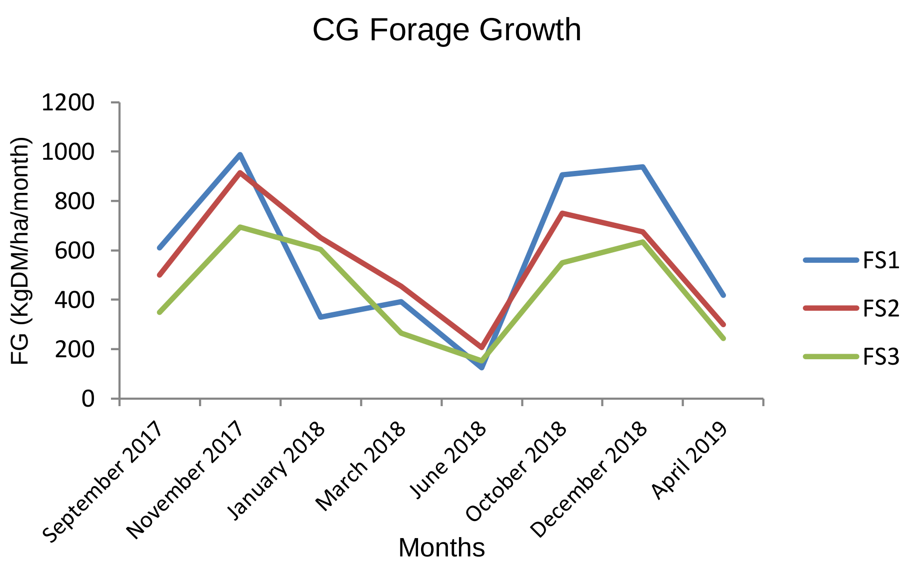

Figure 11. Campos grassland (CG) forage growth (FG) evolution (least square means and standard deviation, not seen since exponential -7) at Farm systems (FS) from September 2017 to April 2019.

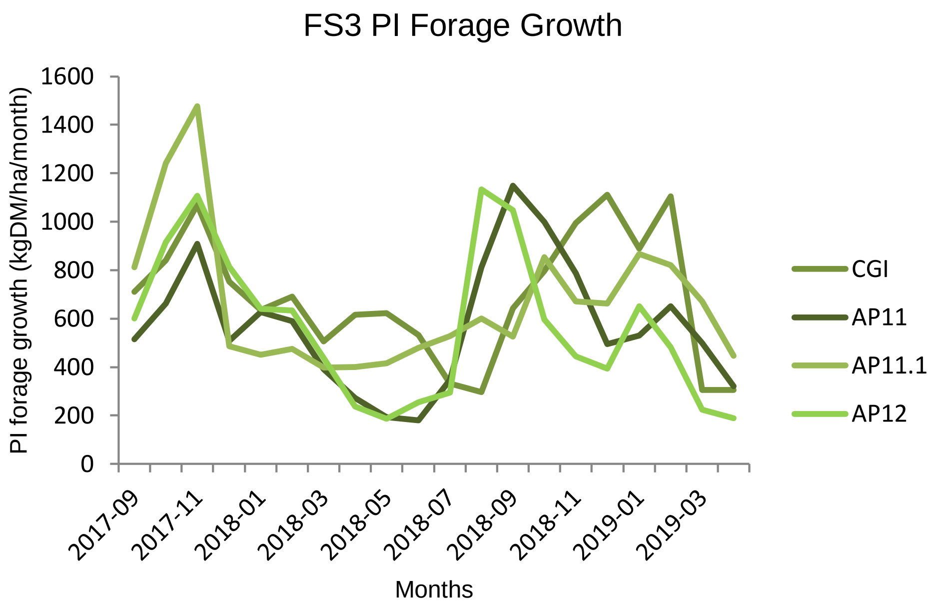

Figure 12. Evolution of forage growth Campos Grassland Improvements (CGI) and artificial pasture (AP11, 11.1, 12) in FS3 during September 2017 to April 2019 (least square means and standard deviation in exponential -6).

The Campos grassland forage growth was affected by the seasonal periods and positively associated to the available soil water (Table 9).

Table 9. Effects of available water and growth seasonal periods on Campos Grassland forage growth response.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept [1]	51.341029	86.68531	0.59	0.5551
Available water[2]	5.7306555	1.145221	5.00	<.0001
Periods (growth)[3]	261.85238	28.80649	9.09	<.0001

[1]Intercept

[2]Monthly available soil water estimated from September 2017 to April 2019 (INIA, GRAS).

[3] Forage growth periods (spring-summer and autumn-winter), forage growth was estimated by satellite images (Paruelo, 2008).

2.4.6.2 Cows relative forage intake

Cow relative DM and metabolic energy intake resulted 43 and 47 % higher respectively ($P < 0.05$) during both BS for the FS3 than for FS1 and FS2 (Figure 13 and 14).

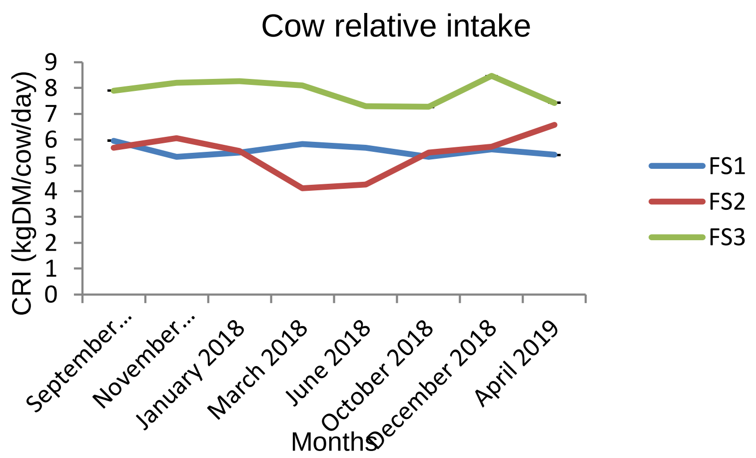

Figure 13. Estimation of cow dry matter relative intake (CRI) at Farms System (FS) from Septemebr 2017 to april 2019 (Least square means and standard deviation in exponential -6).

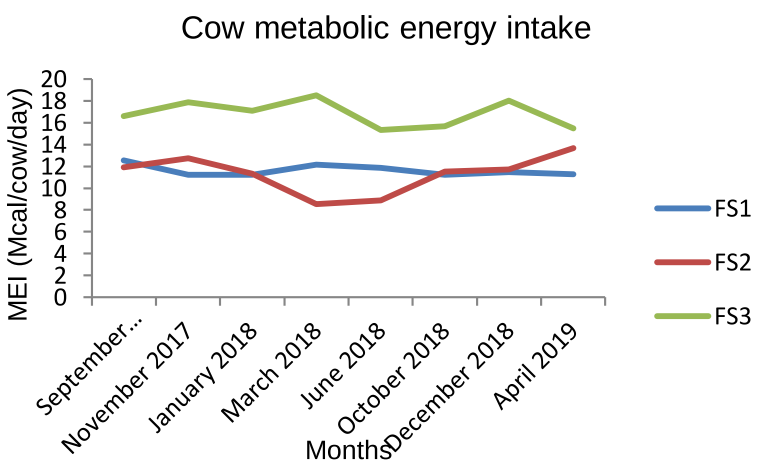

Figure 14. Estimation of cow metabolic energy intake at Farms System (FS) from September 2017 to April 2019 (Least square means and standard deviation in exponential -6).

2.4.6.3 Metabolic hormones concentration

Concentration of IGF-1 concentration was modified by FS and date interaction ($P < 0.05$). Initial concentration of IGF-1 in September 2017 (Spring-Calving) at FS3 resulted 79 and 45 % higher ($P < 0.05$) compared to FS2 and FS1 respectively (Figure 15).

Insulin concentration was modified by FS and date interaction, where insulin resulted 56 and 41 % higher ($P < 0.05$) in FS1 in September 2017, and 52 and 34 % higher in March 2018 compared to FS 2 and FS 3 respectively (Figure 16).

Evolution of leptin serum concentration was not modified by the FS and/or date interaction (Figure 17).

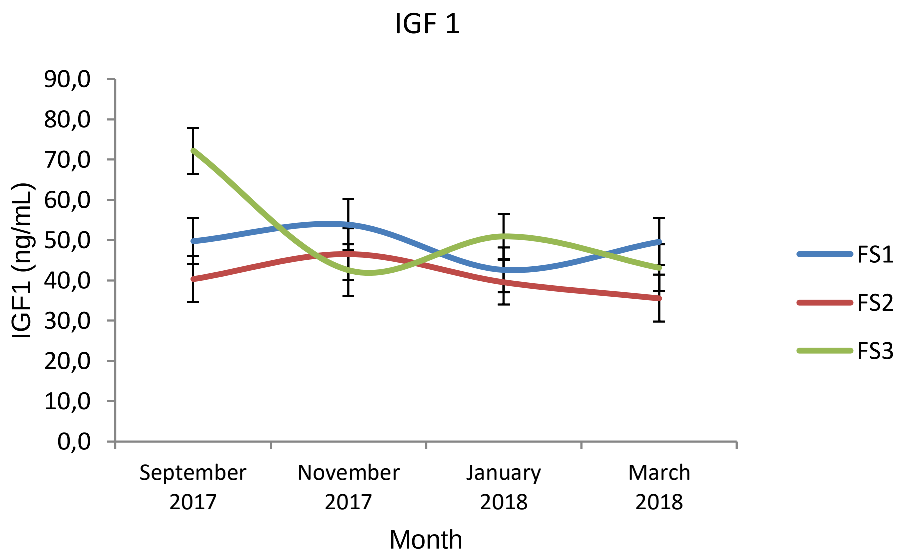

Figure 15. Evolution of multiparous cows IGF1 serum concentration per farm system (FS) from September 2017 to March 2018 (Least square means and standard deviation).

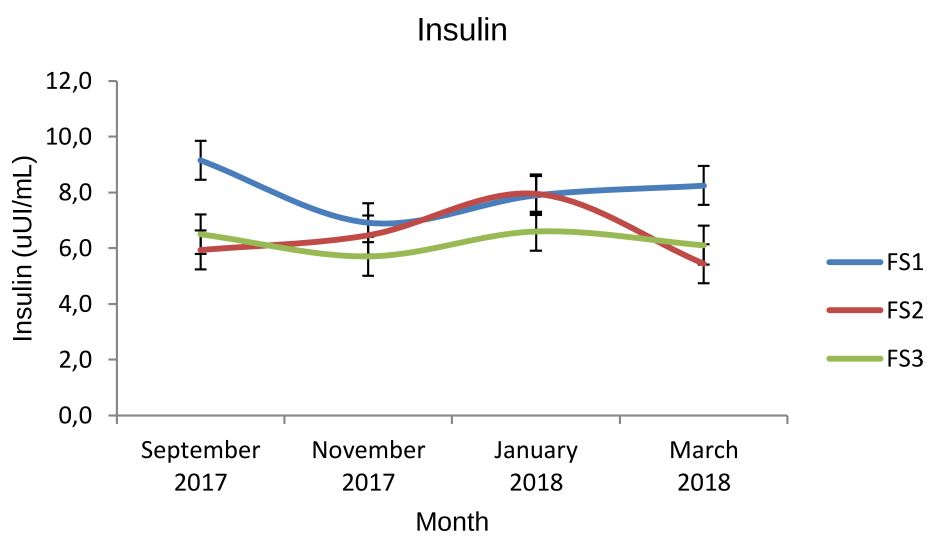

Figure 16. Evolution of Insulin serum concentration per farm system (FS) from September 2017 to March 2018 (Least square means and standard deviation).

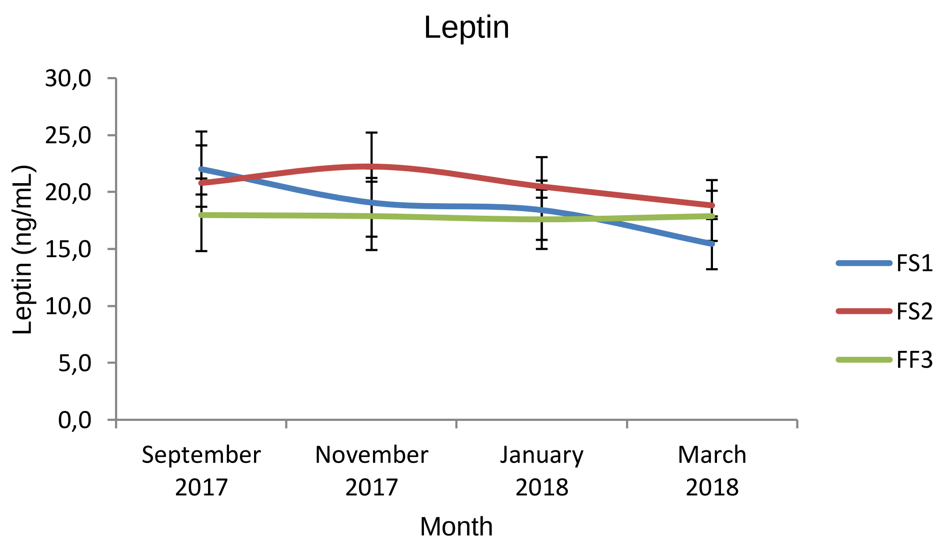

Figure 17. Evolution of Leptin serum concentration per farm system (FS) from September 2017 to March 2018 (Least square means and standard deviation).

Cow IGF1 concentration was possitevely associated (P < 0.05) to calf LW during November 2017 (lactation), also to the increment in cows BCS between September and November 2017 (calving-lactation). For each unit of IGF11 incremented at the beginning of the study (September, 2017) IGF1 serum concentration was incremented (Table 10).

Table 10. Regression model of IGF-1 cow serum concentration response associated to calf live weight in November 2017 (lactation), difference in body condition score (BCS) between November and September 2017 (calving-lactation), initial IGF1 serum concentration in September 2017 (calving), and the interaction between initial IGF1 concentration and delta BCS November-September 2017.

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept[1]	-31.22038	12.74969	-2.45	0.0192
Calf LW Nov.[2]	0.470272	0.09188	5.12	<.0001
DCC2-1[3]	23.781599	5.92957	4.01	0.0003
IGF11[4]	0.7418625	0.130373	5.69	<.0001
(IGF11-53.4402)*(DCC2-1-0.06818)[5]	0.4300476	0.201247	2.14	0.0393

[1] Intercept

[2] Calf live weight on November 2017, lactation period at farm systems, as regressor on IGF-1 serum concentration.

[3] Delta Body Condition Score (BCS) Novemeber-September 2017 as regressor on IGF-1 serum concentration.

[4] Initial IGF-1 concentrations in September 2017 as regressor on IGF1 serum concentration.

[6] Interaction of iitial IGF-1 at calving and delta BCS November-September 2017.

2.5 DISCUSSION

Spatial and temporal grazing management have been associated with higher levels of productivity and not to FS structure (Do Carmo et al., 2019; Cardozo et al., 2015; Ruggia et al., 2015). Paparamborda (2017) and Ruggia et al. (2015) reported levels of 30 % and 23 % higher meat production per hectare respectively associated to STM FS.

Our work showed that beef productivity increased when spatial temporal grazing was applied (133 kg ha^{-1} of beef meat vs 78.6 kg ha^{-1} for STM-FS3 vs TNM-FS1 and TNM-FS2; Table 7). The FH, BCS and kilograms of calf produced are main status variables of cow-calf grazing system on Campos grassland (Soca y Oscasberro, 1992; Short et al., 1990; Do Carmo et al., 2016). Spatial temporal grazing management resulted in a difference of 85% higher FH, with seasonal levels of 6.1 ± 2.1, 7.0 ± 1.3, 6.2 ± 0.9 in spring, summer, autumn and 4.9 ± 0.1 cm winter, associated to higher FA (5.3 ± 1.5, 5.2 ± 0.9, 5.8 ± 0.9, 4.3 ± 0.2 kgDM $kgLW^{-1}$), and to 1 point higher in scale of cows BCS (4.9 ± 0.3) for FS3 (Figure 7, 8 and 9), which was related to 90% more (213 kgs) kilograms of weaned calf per breeding cow compared to TNM.The STM-FS3 FH and FA association to higher levels of cow BCS (Figure 9, $P < 0.5$) can be explained mainly by a resulting 47 % higher MEI (16.8±1.3 Mcal $cow^{-1}day^{-1}$, $P < 0.5$), where cows energy intake is reported to be strongly related to animal performance (Carvahlo et al., 2018; Soca y Pereira, 2000). Moreover, BCS at STM-FS3 was statistical and biological significantly higher at calving, which is associated to the BCS at end of previous autumn (Claramunt et al., 2018) (5.2 ± 0.4 and 5.4 ± 0.5 calving and autumn respectively, $P<0.5$), that based on the reported relationship between BCS at calving and resumption of ovarian cyclicity (Claramunt et al., 2018; Laporta et al., 2013; Soca et al., 2013b; Quintans et al., 2010) contributed to explain the FS reproductive results of 100 % PR (Trujillo et al., 1999; Short et al., 1990) and the overall production of kilograms of weaned calf per breeding cow (Do Carmo et al., 2016 and 2018). STM-FS3 explicitly managed the usage of land (Duru and Hubert, 2003) by a paddock-time grazing combination of CG with 18 % of PI (Figure 6b), such management showed to control the levels of energy intake (Figure 12 and 13) which probably achieved to ensamble most part of the cow energy balance and flux for calf production along the BS (Hess et al., 2005).

The STM-FS3 resulting FH-BCS seasonal relationship resembled the technical proposal of Soca and Orcasberro (1992) for cow-calf management to improve FS reproductive results, and were also similar to the FA-BCS and productive results relationship reported at grazing experiments with treatments of high FA in levels of 5 kgDM $kgLW^{-1}$ (Do Carmo et al., 2016 and 2018).

The TNM-FS1 lack of spatial-temporary grazing management was associated to lower levels of FH (3.3 ± 0.8cm), FA (2.9 ± 0.7 kgDM $kgLW^{-1}$) and BCS (4.0 ± 0.5) that resulted in limited production of kilograms of weaned calf per breeding cow (106.5 kg) and beef meat per hectare (78 kg) (Do Carmo et al., 2018), which was explained mainly by an overall lower MEI (Mcal cow^{-1} day^{-1}, Figure 13) along the BS. TNM-FS1 grazing management (Figure 6) mainly resulted in a constant uncoupled cow energy balance (Hess et al., 2005) along the breeding seasons, which has been largly reported to be associated to low reproductive results (reviewed by Meikle et al., 2018). FS2, also defined as TNM, showed similar levels of associations as FS1 and eventhough it was recently implementing systemic management changes as part of the FS redesign within the ongoing co innovation project, the impacts can not be valorated in the frame time of this study. However, FS1 improved pregnancy rate (92 %, Table 7) during BS2, which can in part be explained by the previous lower PR at BS1, where 37 % of multiparous cows had no calf requierements which probably improved their energy balance, reserves and partition for reproduction at the next mating period in BS2 (Trujillo et al., 1999). In addition, TNM-FS1 decision of an early weaning in February 2019 during BS2 (Table 5), could contribute to explain a redirection of energy for reproduction toward the end of mating period (March, 2019) and therewise improved PR (Do Carmo et al., 2018; Soca et al., 2013c). This early weaning decision constituted another example of isolated practices, since it was not associated to weaned calf nutritional management support, which also contributed to explain low kilograms of weaned calf produced at TNM-FS1 during BS2 (Table 7).

The FS1 and FS2 meat productive results levels (Table 7) resembled last decades national report of cow-calf FS production (DIEA, 2014), also comparable with the results of low FA of 3-4 kgDM $kgLW^{-1}$ treatments at grazing experiments (Do Carmo et al., 2016 and 2018); and to the data reported as baseline of FS at the beginning of INIA co innovation project (Aguerre et al., 2018, Ruggia et al., 2015).

However, CG monthly forage production resulted lower at STM-FS3 (by 300 kgDM ha^{-1} $P<0.05$) during spring-summer (growth period) compared to TNM-FS1, which was not coincident with the reported positive association between FH, FG and also CRI (Do Carmo et al., 2018; Moojen and Maraschin, 2002). Although we considered the methodology (Paruelo et al., 2008) might need further advanced evidence to be concluyent, we do propose that at FS level the interaction with farmer forage management utilization decisions needs to be considered to contribute to explain FG and FH relationship (Ungar, 2019; Briske et al., 2011; Duru, 2013). CG FG was associated to available soil water and the seasonal growth periods ($P < 0.05$) which had been reported as the main factors to explain Campos grassland production (Carvahlo et al., 2007; Berretta et al., 2000). However, lower FG with higher FH and CRI (kgDM $cow^{-1}day^{-1}$) led us to hypothesize that FH levels at STM-FS3 were also explained by a combination of forage utilization strategy of CG and PI paddocks, where and average of 38 % of total herd (heifers and primiparous cows mainly) was grazing at PI during both BS. Also STM-FS3 higher instant stocking rate in levels of 2.2, 1.4, 1.5 AU ha^{-1} during October to January (growth period), in two of the three most used Campos grassland paddocks (Acosta and La llanada) and excluding the calving paddock (Las casas) from this analysis, could contribute to explain part of limited FG results. Integrating some evidence of instant high CG paddock utilization by multiparous cows during CG growth periods can also contribute to explain STM-FS3 explicit priorization of maintaining high cow fat body reserve

(BCS) on grazing management decisions, wich led us to propose that STM-FS3 still has room for improvement in productivity and resilience based on CG production and biodiversity agroecological services (Modernel et al., 2016).

Also grazing management offers an opportunity to buffer the effect of droughts on CG as also found by Cobon et al. (2009). High levels of aboveground biomass are related to deeper and denser rooting system, and these can improve the resilience of grasslands to droughts (Norton et al., 2016). As a result, with higher FA, animal BCS and LW are less affected during drought, which can reduce the reliance on purchases of external feed at elevated costs (FAO, 2013).

Cow body fat reserves are associated to the metabolic status and efficiency for calf production (Chilliard et al., 1998). Likewise, STM-FS3 cow grazing management resulted in higher BCS and IGF-1 serum concentration ($P < 0.05$) at calving, where a positive anabolic signal prior to mating is associated to cow energy partition and efficiency for calf production results (Claramunt et al., 2018; Do Carmo et al., 2016; Soca et al., 2013b; Astessiano et al., 2012; Quintans et al., 2010). Also IGF-1 serum concentration association to calf LW in November 2017 (lactation) was explained mainly by the anabolic signalization and energy partition toward milk production (Gutierrez et al., 2013) that contributed to explain a 28% higher calf daily LW gain (0.94 kg day^{-1}) and the higher calf LW at weaning (90 %, 213 kg) at STM-FS3. The relationship between energy balance, anabolic hormones concentration and productive results had been reported experimentally with similar IGF-1 serum concentration levels in beef cows (Claramunt et al., 2018; Mapfumo et al., 2017; Laporta et al., 2013; Astessiano et al., 2013; Soca et al., 2013a), while higher levels were reported for dairy cattle (Meikle et al., 2013), probably due to an evolutive liver metabolism development for high milk production requirements.

Insulin and leptin serum concentration were not related to the different BCS and metabolic status of the FS cows. Eventhough insulin serum concentration was higher during two measurements in FS1 ($P < 0.05$), it can be more dependent on short term cow intake (reviewed by Meikle et al., 2018; Evans et al., 1975). Also, an insulin resistant metabolic condition reported in dairy cows manily was associated to long term low energy intake and LW loss, which could contribute to explain higher insulin concentration in cows at TNM-FS1 (De Koster and Opsomer, 2013). Leptin concentration was not different among FS. Probably a more contrasting cow fat deposition (BCS) needs to be tested to express differences in this hormone serum concentration, since it had been largely reported to be associated with fat tissue metabolism status is several species (Delavaud et al., 2013; Chilliard et al., 1998).

The STM-FS3 grazing management, integrated to jerarquized cow-calf practices to enhance cow energy intake and balance resulted in higher nutritional and endocrine levels, which could be evidenced within this study by higher levels of heifers LW at 24 months of age (Table 5), cows BCS and IGF-1 concentration (Figure 9 and 15). Also, STM-FS3 had a trajectory of high BCS levels registered by a previous project (Aguerre et al., 2018), which could all together contribute to evidence the herd high nutritional-metabolic status that could probably contributed to explain the unmodified reproductive and productive high results for both BS (Table 7), despite a 35 % reduction of FH and FA during BS2 (Table 8) compared to BS1, based on a process known as metabolic memory (Blanc et al., 2006; Chilliard et al., 1986). This animal adaptative metabolic response could constitute a source of herd flexibility and resilience for FS faced with environmental uncertainty (Fringgens et al., 2017; Puillet 2017; Nocieres et al., 2011).

The overall differences in FS management decisions could be associated in part to a preexisting trajectory in participative learning process (Aguerre et al., 2018; Albicette et al., 2017), which in STM-FS3 implied at least a monthly joint revision and discussion between farmer and project field advisor focused on farm redesign for calf production during 5 years previous to this study (Aguerre et al., 2018; Albicette et al., 2017; Ruggia et al., 2015). Also, STM-FS3 could be associated to a reported Technological farmer type (Lauric et al., 2010) described as open minded farmers willing to adopt technologies of process innovation, considering the FS innovative pathway and the continued enrollment in participatory projects. The fact that STM-FS3 lived at the farm with no other working activities, different from FS1 and FS2, had been analyzed regionally as one of the barriers for FS innovation transition (Fernandez Rosso et al., 2020) and may be related to focus, time and motivation for farm activity and innovation pathway. This farmers profile could also be associated to the famers identified by peers as exemplary for FS performance, and were also reported to stand out when confronted to use of science-base criteria (Dumont et al., 2020). Farmers, researchers and advisor's participative knowledge construction process, along with scientific methodology can promote significant learning pathways for FS agroecological redesign (Dumont et al., 2020).

Overall FS are complex systems that integrate climate, soil, forage, animal and human variables in time and space dimensions (Briske et al., 2011; Boyd and Svejcar, 2009), where space-temporal grazing management is a complex proccess itself that manipulates forage, animal and ecosystems response and their relationships in space and time to improve productive levels without harming the ecosystem (George et al., 2016; Blumetto et al., 2019). Therefore, understanding the complexity and level of relationships between farmer management decissions and biological variables-processes response contribute to management science based (Nociere et al., 2011; Duru, 2013) adaptative and systemic approach for cow-calf FS agroecological redesign (Norton, 2016) to improve sustainability and alliviate climate change effects on Campos grassland.

2.6 CONCLUSSIONS

Spatial-temporary grazing management explained most part of productive results at the FS and was associated to seasonal evolution of FH and FA in levels de 6.4 ± 0.5 cm and 5.4 ± 0.3 kgMS $kgLW^{-1}$ respectively during spring, summer and autumn, 4.2 ± 0.1 cm and 4 ± 0.2 kgDM $kgLW^{-1}$ in winter, and levels of 4.9 ± 0.3 points of cows BCS (scale 1-8), associated to central processes as cow MEI and anabolic status that resulted in 213 kilograms of weaned calf per breeding cow which was also associated to 58 % more beef meat per hectare production compared to TNM FS during two breeding seasons.

Campos grassland spatial-temporary grazing management combined strategically with levels of 18 % of PI and integrated to jerarquized cow-calf practices was associated to previous co innovation trajectory, and resulted in levels of productivity, that without increasing costs, contributed to improve cow-calf FS sustainability and can alleviate forage shortage event on Campos grassland. Cow-calf FS redesign based on spatial-temporary management science can constitute an opportunity for agroecological sustainability in Río de la Plata Campos grassland.

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3. DISCUSIÓN GENERAL

Los resultados productivos a escala de SGF fueron mayormente explicados por la gestión y no por la estructura. El SGF3 gestor espacio temporal (GET, Paparamborda, 2017) mejoró un 58 % la producción de carne vacuna (132 kg ha^{-1}) con respecto a los SGF no gestores (NG, Paparamborda, 2017). Esta superioridad coincide con la respuesta a un proceso de coinovación en SGF del Este del Uruguay (Aguerre et al., 2018) donde se aplicó la propuesta técnica de manejo de rodeo de cría de Facultad de Agronomía-Universidad de la República (Soca y Orcasberro, 1992), integrada a la suplementación de terneras al primer invierno y utilización de pasturas mejoradas para vaquillonas (Quintans et al., 2010) y primíparas, promoviendo el desarrollo de un modelo GET (Cardozo et al., 2015, Ruggia et al., 2015). También resulta coinicidente con los resultados de la encuesta del proyecto Ganaderos Familiares y Cambio Climático (GFCC, proyecto nacional interinstitucional del Ministerio de Ganadería Agricultura y Pesca, Uruguay) donde se encontró que los GET produjeron un 30 % más ($P < 0,05$) de carne vacuna por hectarea comparado con los NG (Paparamborda, 2017).

Estos resultados confirman que en Uruguay existe una importante brecha de rendimiento entre la investigación y los resultados productivos y que las propuestas de intensificación ecológica permiten aumentar la producción de carne en niveles de sostenibilidad y sin modificar los recursos asignados al proceso.

Las decisiones de manejo del pastoreo del SGF3 definido como GET (SGF3-GET) integraron principalmente información animal de CC, edad y estado fisiológico de las vacas, altura de forraje (AF) del CN, y una utilización estratégica de 18 % de área de pasturas mejoradas, en el espacio y en el tiempo. Esto permitió describir la secuencia de uso de potreros y recursos en tiempo y espacio por parte del productor (Figura 6b), lo cual ha sido la base de modelos conceptuales sobre decisiones de pastoreo en SG (Duru y Hubert, 2003). El SGF3-GET integró un modelo de gestión de patoreo, con prácticas de manejo de la cría vacuna estratégicas orientadas a controlar el flujo de energía durante el ciclo de cría, como ser (Tabla 4 y 5): momento y duración del entore y partos (Beaucarne 2019, Funston et al., 2016) con diferencias por categoría y decisiones adaptativas como acortar el entore del primer año de acuerdo a los altos resutados de preñez temprana (88 %) obtenidos en el diagnóstico de actividad ovárica; la priorización nutricional de vaquillonas (Quintans et al., 2010) y vaca primíparas que pastorearon mayormente en los mejoramientos durante el período parto-destete, así como las multíparas con inferior CC; sumado a prácticas para redireccionar la energía hacia reproducción como el destete temporario al comienzo de entore (Do Carmo et al., 2018, Soca et al., 2013 b y c).

A la vez, el SGF3-GET implementó destete definitivo temprano en otoño, incluso diferenciado y anterior en la categría de prímiparas durante el segundo año, lo que contribuiría a explicar los cambios en CC durante Otoño y entrada de invierno (Claramunt et al., 2018). La suplementación energética de las terneras durante el primer invierno permitiría mejorar el balance de energía durante la estación más restrictiva, lo que contribuye a construir una trayectoria de niveles metabólicas superiores desde etapas tempranas en la reposición del rodeo de cría y estaría asociado a su futura performance reproductiva (Quintans et al., 2010).

Las decisiones de manejo estrátegicas y adaptativas, que integran la gestión del pastoreo conjuntamente con las prácticas de gestión orientadas a regular el flujo de energía hacia producción de kilos de terneros (Hess et al., 2005) vía mejoras en el peso y número de terneros, contribuyeron a explicar niveles de producción superiores sobre campo natural en un sistema GET (Tabla 7).

En SGF3-GET se encontraron niveles de AF de 6,4 ± 0,5 cm y 5,4 ± 0,3 kgMS kgPV^{-1} de OF durante la primavera-verano-otoño y a 4,2±0,1 cm y 4,0 ± 0,2 kgMS kgPV^{-1} respectivamente durante el invierno. Estos niveles de AF y OF fueron superiores ($P < 0,05$) a los registrados en SGF1 y SGF2 (3,4 ± 0,1 cm y 3,0 ± 0,1 kgMS $kgPV^{-1}$ respectivamente) y contribuyen a explicar las mejoras en los niveles de CC de las vacas de 5,2 ± 0,4 y de 5,4 ± 0,4 en otoño (Claramunt et al., 2018). Estos niveles de CC contribuyen a explicar los niveles de TP (100 %) de GET (Trujillo et al., 1999, Soca y Orcasberro 1992, Short et al., 1990)

La superior CC del rodeo en SGF3 podría explicarse en gran parte por los niveles de consumo 47 % superior ($P < 0,05$) de energía metabolizable obtenidos (16,8 ± 1,3 Mcal $vaca^{-1}$ $día^{-1}$, Figura 13 y 14) asociados a la gestión del pastoreo por AF en los potreros y en los diferentes momentos que contribuye al control de la OF (Figura 6b y 8), lo que estaría asociado finalmente a la performance animal (Carvahlo et al., 2008, Soca y Pereira 2000). Mayor consumo y balance de energía explicarían mayores reservas de tejido adiposo y CC, lo cual está relacionado a un estado metabólico superior de la vaca de cría (Claramunt et al., 2018, Laporta et al., 2013, Astessiano et al., 2013, Meikle et al., 2013, Soca et al., 2013a, Chilliard et al., 2006). En este sentido, los niveles de IGF-1 obtenidos estuvieron asociados al incremento de CC en el período entre setiembre y noviembre 2017 ($P < 0,05$) que corresponde mayormente al período de parto-lactancia, a los niveles iniciales de IGF-1 ($P < 0,05$) en setiembre 2017 (parto) y también al peso de los terneros en noviembre 2017 durante la lactancia ($P < 0,05$) (Tabla 10). Donde niveles superiores de IGF-1 al parto (79 % superior, 72 ug mL^{-1}), hormona reportada como señal anabólica clave en el flujo y partición de energía (Hess et al., 2005), estarían asociados a una mayor actividad ovárica, fertilidad (Soca et al., 2013b, Quintans et al., 2010) y producción de leche (Gutierrez et al., 2013), lo que contribuye a explicar resultados superiores de tasa de preñez (100 %), de ganacia diaria de terneros (0,94 kg $día^{-1}$) y de kilogramos de ternero destetados por vaca entora a los 205 días posparto (213 kg) en el sistema GET (Do Carmo et al., 2016 y 2018).

El presente trabajo confirma que a nivel de SGF la gestión espacio-temporal contribuye a mejorar las principales variables de estado del sistema de cría vacuna en campo natural como la cantidad de forraje, la CC y los kilos de ternero destetado por vaca entorada. Dichos cambios serían posibles porque se modifican procesos centrales como el consumo y la eficiencia de uso de la energía de las vacas de cría que aumentan el flujo de energía hacia producción, y contribuye a explicar los niveles superiores de producción de kilogramos de terneros destetados por vaca entorada y de carne vacuna por hectarea en SGF sobre campo natural (Do Carmo et al., 2018, Short et al., 1990) (Figura 4).

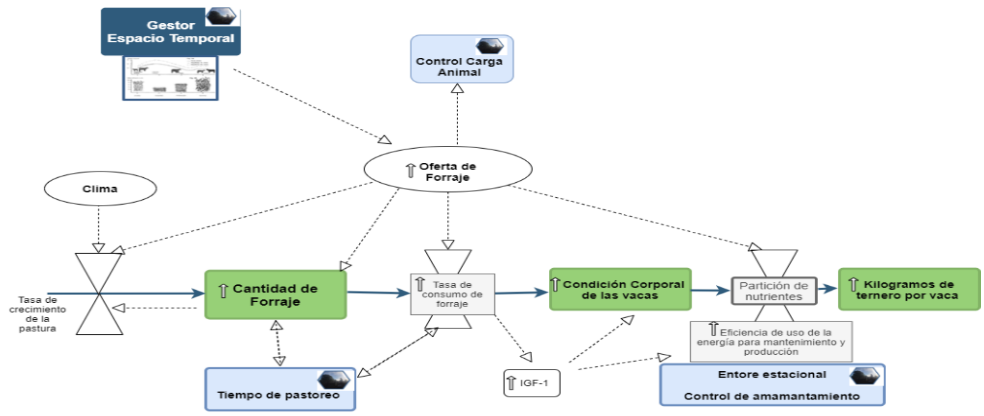

Figura 4. Modelo conceptual que integra la gestión espacial y temporal de pastoreo con las variables de estado y procesos que mejor explican la producción de kilogramos de ternero destetado por vaca enotrada en el sistema ganadero criador sobre campo natural (modificado de Do Carmo et al., 2018; integra Claramunt et al., 2018, Paparamborda 2017, Soca y Orcasberro 1992).

Sin embargo, en el presente trabajo no se encontró una una asociación positiva entre AF y crecimiento de forraje (CF) como ha sido ampliamente reportado (Berretta et al., 2000). El CF resultó explicado por el agua disponible en el suelo y a la estación de crecimiento (primavera-verano) ($P < 0,05$), ambas reportadas como las variables que explican mayormente el CF en CN (Berretta et al., 2000). La estimación de CF se llevó a cabo con datos provenientes de imágenes satelitales lo cual puede no ser una herramienta que permita estimar con precisión cambios en el CF con el estado de la pastura principalmente relacionado a una posible subvaloración del forraje seco. Sin embargo, entendemos que a nivel de sistemas es pertinente considerar y analizar la gestión y decisiones de utilización del forraje en el tiempo y espacio para explicar la AF resultante (Ungar 2019, Briske et al., 2011, Duru 2013). Los resultados sobre la mejora en la AF y consumo de forraje, pero reducción del CF del campo natural en el SGF3 ($P<0,5$) con respecto a SGF1, nos llevan a hipotetizar que esta relación no lienal podría estar explicada por los niveles de utilización estratégica del 18 % de pasturas mejoradas, las cuales fueron utilizadas por el 38 % del total del rodeo (principalmente vaquillonas, vacas primíparas y multíparas con baja CC) en ambos ciclos de cría. A su vez, un manejo con altas cargas relativas e instantáneas registradas (1,5 a 2,2 UG ha^{-1}) en dos de los tres potreros de campo natural más utilizados durante los meses de crecimiento (octubre a enero), podría contribuir a explicar los niveles inferiores de CF registrados durante primavera y verano en el SGF3 GET (Figura 11). Planteamos entonces que el SGF3 GET si bien puede que no produzca más pasto, utilizaría mejor la combinación de sus recursos de CN y pasturas mejoradas, logrando mejores niveles de consumo, balance de energía y resultados productivos que los SGF1 y SGF2 NG, por lo que aún tendría potencial de mejora en sostenibilidad y resiliencia basado en una mejora de producción del CN. Este caso podría constituir entonces un ejemplo de cómo la gestión y utilización del forraje manipula la respuesta y las relaciones de los procesos biológicos (George et al., 2006) que no resultan lineales, lo que aumenta la complejidad para su comprensión (Briske et al., 2011, Boyd and Svejcar 2009) y justifica continuar las mediciones y análisis de las variables y sus relaciones a nivel de SGF.

A su vez, en este trabajo el SGF3-GET demostró mantener los niveles superiores de tasa de preñez y producción de carne por hectárea durante los dos años del estudio (Tabla 7), no obstante, una reducción del 35 % de AF y OF en el segundo año del estudio (Tabla 8). En dicha respuesta, por el lado animal, podría estar involucrado el proceso conocido como memoria metabólica, asociado a una capacidad de adaptación para mejorar la eficiencia del metabolismo tisular, y en el comportamiento de pastoreo de las vacas (Blanc et al., 2006, Chilliard et al., 1998). Donde la capacidad de la vaca para adaptarse a una restricción nutricional dependería de sus reservas corporales, su estado metabólico (Claramunt et al., 2018, Mapfumo et al., 2017, Astessiano et al., 2013, Laporta et al., 2013, Soca et al., 2013a) y de la intensidad y frecuencia de los eventos restrictivos (Blanc et al., 2006). En este sentido el SGF3 GET además del nivel superior de CC (Figura 9) e IGF-1 (Figura 15) al parto de las vacas de cría, los niveles de AF previos no eran tan limitantes, lo que posiblemente sumado un manejo adaptativo (Duru y Hubert 2003) del pastoreo que contribuyera a compensar parte del aporte energético durante la escasez de forraje, podría contribuir a explicar los niveles de producción sostenidos. La memoria metabólica de las vacas a su vez, se relaciona con una trayectoria previa de altos niveles nutricionales, de reservas de grasa corporal, y estado metabólico (Blanc et al., 2006, Chilliard et al., 1998). En este sentido, el SGF3-GET presentaría una trayectoria de alto nivel de reservas de energía corporal asociadas a los registros de CC (4,9 ± 0,3 en la escala 1-8) tanto en este estudio como en estudios previos que incluyeron al SGF3 (Aguerre et al., 2018); sumado a la información del PV de las vaquillonas a los 24 meses de edad (Tabla 5), en niveles de 100 kilogramos por encima del promedio de SGF1, SGF2 y de los niveles reportados (Quintans et al., 2010). El manejo nutricional estratégico y energético de la recría en su primer invierno, el de vaquillonas y vacas primíparas sobre pasturas mejoradas durante todo el ciclo de cría parto-entore-destete (Figura 6b y Tabla 5), evidenciarían un nivel nutricional energético superior desde la concepción en SGF3-GET. En este sentido, la memoria metabólica de las vacas se construye en el tiempo y podría constituir una herramienta importante de flexibilidad y capacidad de adaptación de los rodeos frente a eventos restrictivos (Fringenns et al., 2017, Nociere et al., 2011) la cual, integrada al manejo del uso de la tierra, producción de forraje y biodiversidad del campo natural como servicio ecosistémico (Modernel et al., 2019) contribuiría a aliviar los efectos adversos del cambio climático en los SGF sobre campo natural.

Los resultados de producción de carne vacuna promedio de 132 kg ha^{-1} en los dos años del estudio están asociados a un proceso de intensificación en el manejo espacial y temporal de los recursos y procesos en el SGF3-GET asociado a una trayectoria de coinnovacion y rediseno previa (Aguerre et al., 2018, Ruggia et al., 2015). Los resultados obtenidos fueron comparables a los propuestos como objetivo nacional productivo para el año 2030 (128 kgPV ha^{-1}) en base a un de modelo de producción de carne bovina en SG (Soares de Lima, 2009) desarrollado en el marco de los Objetivo de Desarrollo Sustentable (SDSN, 2015) para la ganadería en Uruguay. Dicho modelo productivo plantea centralmente la incorporación de suplementación e insumos al proceso para lograr alcanzar los niveles objetivo de producción (Kanter et al., 2016), en este sentido podría ser necesario considerar las limitantes de implementación de tecnologías de insumos en SGF que ya presentan problemas de sostenibilidad (Michalscheck et al., 2018). Sin embargo, a partir de los antecedentes (Do Carmo et al., 2019, Ruggia et al., 2015, Cardozo et al., 2015) y de los resultados obtenidos en el presente estudio consideramos que es posible proponer alcanzar resultados productivos sustentables en base a tecnologías de proceso con el manejo espacio-temporal del pastroreo como eje central, para controlar el nivel de forraje ofertado a las vacas de cría, el consumo y acople del balance de energía, integrado a prácticas de manejo de la cría vacuna de bajo costo priorizadas según su impacto en el control del flujo de energía hacia producción de ternero durante el ciclo de cría. En este sentido en el SGF3-GET la gestión espacio temporal de pastoreo del campo natural fue central, y estuvo asociada estratégicamente a un 18 % de pasturas mejoradas para vaquillonas y vacas primíparas principalmente, lo que coincide con la asociación entre mayor productividad y niveles de 20 % de intensificación de pasturas reportados por González et al. (2020) y un nivel de suplementación estratégico durante la recría en niveles de 10,5 kg ha^{-1} $año^{-1}$, inferior al valor de referencia de base nacional de 19,0 kg ha^{-1} $año^{-1}$ (Kanter et al., 2016). Esto confirma que la GET sistémica, controla los procesos biológicos que mejor explican los resultados productivos y contribuye a mejorar la sostentabilidad de los SGF en sistemas pastoriles sobre campo natural.

Sin embargo, uno de los mayores desafíos que enfrenta la cría a nivel regional parece ser las barreras (Fernandez Rosso et al., 2020, González et al., 2020, Coquil et al., 2018) que limita la adopción de prácticas de tecnologías de proceso disponibles para el productor (Gómez-Miller y Saravia, 2016). En este sentido el enfoque de aprendizaje social participativo (Rossing et al., 2010) ha demostrado ser una metodología exitosa para recorrer el camino de rediseño de los SGF hacia una intensificación sostenible sobre campo natural (Albicette et al., 2017, Dogliotti et al., 2014, Falconnier et al., 2017).

Fernandez Rosso et al. (2020) discutieron las barreras de adopción identificadas en SGF del Río de la Plata que incluían tamaño del predio, vocación y tiempo de dedicación a la actividad ganadera, sucesión de generaciones, falta de valoración adecuada de la asistencia técnica y de la mano de obra y vivienda. Y muy importante reportaron la percepción negativa de productor tradicional a las propuestas de cambios, y específicamente lo relacionado con el trabajo con más forrajes, asociado a la presencia de malezas, etc. a pesar de la asociación ampliamente reportada entre mayor AF y OF con mayor producción y resultados económicos (Do Carmo et al., 2018, Claramunt et al., 2018, Cardozo et al., 2015, Nabinger et al., 2009, Soca et al., 2007). La combinación de limitantes que involucra a productores, investigadores, técnicos, responsables de políticas públicas pueden explicar en parte la baja adopción de tecnologías de proceso en los sistemas tradicionales (Paparamborda 2017, Oyhantçabal 2003, Pereira 2003, Gómez-Miller y Saravia 2016), y la necesidad de enfoques participativos que involucren al productor con el técnico predial en un proceso de aprendizaje social (Coquil et al., 2018, Albicette et al., 2017).

Los SGF son sistemas complejos que para su estudio y análisis requieren un enfoque sistémico y adaptativo, debido a que integran mútliples variables biológicas y humanas en el espacio y tiempo que complejiza a su vez la comprensión y conocimiento de sus relaciones (Briske et al., 2011, Boyd y Svejcar 2009). El presente trabajo intentó contribuir a aportar información detallada cuali y cuantitativa a nivel de sistemas, que relaciona las decisiones en gestión espacio-temporal del pastoreo (Duru y Hubert, 2003) con los procesos biológicos que contribuyen a explicar la respuesta vegetal, animal, resultados reproductivos y productivos de los SGF criadores sobre campo natural. Conocer la magnitud y relaciones de las variables que definen y explican en gran parte los sistemas asociadas a la gestión predial, podría contribuir a la toma de decisiones en el rediseño hacia una intensificación agroecológica para mejora la sostenibilidad y reducir la vulnerabilidad ante eventos climáticos de los SGF sobre campo natural.

4. CONCLUSIONES

Los SGF presentan un potencial productivo basado en la gestión espacio temporal del pastoreo que demostró ser una hermamienta que mejora los resultados de producción de carne en niveles de sustentabilidad, sin modificar los recursos asignados al proceso. La gestión espacial y temporal del pastoreo como eje central, integrada a prácticas estratégicas en la cría vacuna, estuvieron asociadas a niveles de AF y OF de 6.25 cm y 6 kgMS $kgPV^{-1}$ respectivamente en primavera, verano y otoño y de 4,2 cm y 4 kgMS $kgPV^{-1}$ en invierno, asociadas a niveles de 5,2 y 5,4 puntos de CC (escala 1-8) al parto y en otoño, y 213 kilogramos de terneros destetados por vaca entorada (205 DPP) y 132 kilogramos de carne vacuna por hectárea en promedio de los dos años del estudio. La relación entre la gestión espacio-temporal del pastoreo y los resultados superiores de las variables de estado y resultados productivos del sistema, estuvieron asociadas al control de procesos centrales como son el consumo de energía y estado metabólico de las vacas de cría. Las decisiones de manejo modificaron la respuesta vegetal y animal en relaciones no lineales en tiempo y espacio, dicha complejidad justifica un enfoque sistémico que integre decisiones estratégicas y adaptativas basadas en un proceso de aprendizaje participativo con mediciones y metodología científica para el rediseño hacia una intensificación agroecológica de SGF sostenibles y más resilientes sobre campo natural.

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6. ANEXO

6.1 ASOCIACIONES ENTRE VARIABLES

En el Cuadro 1 se presentan las asociaciones significativas (P < 0,05) entre las variables medidas en los SGF, a partir de las cuales se seleccionaron las regresiones a testar.

Cuadro 1. Coeficientes de correlación Pearson: asociaciones significativas entre las variables medidas a nivel de sistemas ganaderos familiares.

	CC[1]	CC1[2]	PV[3]	PV1[4]	CR[5]	IGF-1[6]	IGF-1 1[7]
AF[8]	0.48	0.69	0.58	0.74	0.81	0.15	0.43
P[10]	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
CC[1]	1	0.78	0.78	0.63	0.53	0.28	0.44
P[10]		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
CC1[2]	0.78	1	0.7	0.83	0.71	.	0.61
P[10]	<.0001		<.0001	<.0001	<.0001	NS	<.0001
PVt2[9]	.	.	.	.	.	0.502	.
P[10]	.	.	.	.	.	0.003	.

1 Condición corporal de las vacas de cría (escala 1-8, Vizcarra et al, 1986).
2 Condicion corporal en setiembre 2017 (período parto).
3 Peso vivo de las vacas de cría medido en kilogramos.
4 Peso vivo de las vacas de cría en seteimbre 2017 (período parto).
5 Consumo relativo de las vacas de cría estimado en kg de materia seca por vaca por día (CSIRO, 1990).
6 Concentracíon sérica de la hormona IGF-1 en vacas de cría.
7 Concentración inicial de IGF-1 en Seteimbre 2017 (período parto).
8 Altura de forraje promedio de los sistemas ganaderos (Do Carmo et al., 2020)
9 Peso vivo de los terneros en noviembre 2017 (periodo parto-lactación)
10 P valor de significancia estadística de la asociación