RESUMEN

El calentamiento global origen del fenómeno de cambio climático observado en las últimas décadas, introduce uno de los mayores desafíos para el futuro de la humanidad. La tecnología provee medios para mitigar sus consecuencias, en particular en cuanto a su impacto sobre la producción agropecuaria. El objetivo general de esta tesis fue evaluar el impacto del cambio climático global sobre el comportamiento de las precipitaciones en los partidos de Bahía Blanca y Coronel Rosales, en el sur del la Provincia de Buenos Aires (Argentina). Posteriormente, generar un modelo predictivo que permita estudiar la respuesta productiva y económica de la aplicación de distintos niveles de tecnología sobre las empresas ganaderas de esta región, en función de la distribución de la precipitación del clima actual y frente a las señales de cambios observadas a partir de la evolución del calentamiento global. Más precisamente, sus objetivos específicos fueron: 1) cuantificar y comparar la distribución de la precipitación anual, estacional y de ocurrencia de anomalías dentro del área de estudio y determinar su grado de homogeneidad espacial. 2a) evaluar la existencia de evidencias de cambio climático en la distribución de la precipitación regional hasta el presente y cuantificar el nivel del cambio. 2b) estudiar a partir de los modelos de circulación global de la atmósfera mundiales más confiables en la actualidad, el comportamiento esperado en la distribución de la precipitación regional en respuesta al calentamiento global para el futuro cercano (2012- 2050). 3a) desarrollar un modelo de simulación bioeconómico para analizar el comportamiento productivo de los sistemas ganaderos del área de estudio, en respuesta a la distribución de las precipitaciones específica de esta zona. A partir del modelo, determinar el riesgo productivo y económico actual del sistema modal de la región caracterizado por un bajo nivel tecnológico, respecto a uno propuesto para mejorar la sustentabilidad regional, de alta tecnología. 3b) En función del modelo desarrollado, analizar el impacto del cambio climático previsto de las precipitaciones, sobre el riesgo productivo y económico de los dos sistemas tecnológicos bajo estudio. El análisis se realizó a partir de 10 registros pluviométricos de más de 40 años de antigüedad, distribuidos en la región de estudio. En función de los mismos determinamos las distribuciones estocásticas de ocurrencia de la precipitación en el área, mientras que a partir del registro de mayor antigüedad (1860-2011), evaluamos los efectos del calentamiento global sobre dicha distribución. Posteriormente, construimos un ensamble con los modelos de circulación global de la atmósfera, más confiables en la actualidad, que fue anidado al modelo de circulación regional Weather Research and Forecasting Model, para estudiar las señales de cambio, en la variable precipitación, para la región de estudio en el futuro cercano (2012-2050), bajo el escenario A2 de cambio climático. Esta información fue incorporada en el desarrollo de un modelo bioeconómico de simulación de los sistemas ganaderos zonales. Este modelo se denominó con la sigla “MBBCR” y se estructuró a partir de la integración de tres componentes principales: 1) las funciones matemáticas de densidad de probabilidad de la precipitación determinadas para ambos contextos climáticos (presente y futuro cercano), 2) las ecuaciones de respuesta de los recursos forrajeros zonales frente a la precipitación estacional, determinadas por análisis de regresión a partir de dos experimentos de campo de forrajeras que se llevaron adelante desde 2005 a 2011, 3) los algoritmos para la predicción de respuesta animal en sistemas pastoriles desarrollados por el sistema australiano de requerimientos nutricionales para animales domésticos. Dicho modelo, nos permitió estudiar el efecto de la distribución de la precipitación del clima presente y la esperada en el futuro, sobre el sistema

modal de la zona y la propuesta de mayor adopción de tecnología. Los resultados más importantes de este trabajo fueron que la región de estudio presentó un alto grado de homogeneidad en el comportamiento de la precipitación en su cobertura espacial. Se encontraron evidencias de que el calentamiento global, ha generado modificaciones significativas en el patrón de las distribuciones históricas de lluvias de la región, a partir de la década de 1960, donde se visualiza el inicio de cambios sustantivos en la temperatura media global. En este sentido, la mediana de la precipitación anual se incrementó en un 28,9% ($p<0,0001$) en el periodo 1961-2011 respecto a 1860-1960. Las señales de cambio climático para el futuro cercano (2012-2050, A2) mostraron la posible introducción de otra nueva modificación en el patrón de precipitaciones anuales y estacionales tendientes a un aumento de las mismas en verano (+36,3%) y otoño (+43,9%) y una reducción en primavera (-11,2%) con respecto al periodo 1961-2011 ($p<0,0001$). El sistema de mayor adopción de tecnología expuso niveles medios significativamente superiores ($p<0,0001$) en la distribución de probabilidades de la producción de carne neta (+166% y 255%) y del resultado económico (+479% y 1077%) frente a los observados en el sistema modal, para ambos escenarios climáticos: presente y proyectado (2012-2050, A2), respectivamente. El sistema de mayor aplicación de tecnología manifestó un menor nivel de riesgo, dado por una probabilidad del 0,03% de presentar un nivel de producción de carne neta inferior a 70 Kg. ha^{-1} $año^{-1}$, cuando en el sistema modal la probabilidad de superar este nivel sería solamente de un 1,37%. Estas diferencias en los niveles de probabilidad se hicieron más pronunciadas frente a la variabilidad de la precipitación esperada en el futuro cercano bajo el escenario A2 de cambio climático. Concluimos de esta manera, que la propuesta de mayor tecnología se presenta como una alternativa tecnológica para la ganadería esta región, de menor riesgo en sus niveles de producción y resultado económico, cuando fue evaluada frente a la totalidad de la variabilidad del clima actual de la región. Asimismo, se presenta como una estrategia sistémica de mitigación de los efectos negativos que pudieran manifestar el acontecimiento de las señales de cambio climático global previstas para la región de estudio sobre el comportamiento de la precipitación.

PALABRAS CLAVES: Riesgo Climático, Riesgo Económico, Empresa Agropecuaria, Región Semiárida, optimización tecnológica.

SUMMARY

Global warming, revealed by the observed climate changes of the last decades, poses one of the main challenges to the future of human life on Earth. Technology provides means to alleviate its effects, in particular its impact on agricultural production. The general objective of this thesis is to evaluate the impact of climate change on the pattern of precipitation in the departments of Bahía Blanca and Coronel Rosales, at the southwest of the province of Buenos Aires (Argentina) and propose technological solutions for the livestock systems to mitigate its consequences. To carry out this assessment we develop a predictive model of productive and economic responses to the application of technology livestock at farms, conditioned on the current rainfall distribution and the future pattern inferred from the expected climate changes. More precisely, the specific objectives of the thesis are: 1) to determine the degree of spatial homogeneity of the distribution of annual precipitation and the seasonal occurrence of anomalies in the area under study; 2a) to evaluate the evidence of climate change in the historical series of rainfall, quantifying the level of change; 2b) to derive, from the most reliable global circulation models of the atmosphere, the expected distribution of precipitation in the near future (2012-2050); 3a) to develop a bio-economic simulation model of productive performance of livestock systems focusing on the possible response to the rainfall distribution in the region. Using this model, we compare the current economic production risk in a modal system (of low technological level) of the region with one designed to improve the degree of sustainability with high technology. 3b) with the same model we analyze the impact of projected climate change on the production of the two technological systems under study. The analysis starts deriving from 10 regional pluviometric records of over 40 years old, the precipitation distribution in the area. Using the data from the longest entry (1860-2011) we evaluate the effects of global warming on these distributions. Then, we build an ensemble with the most reliable global circulation models of the atmosphere and a regional circulation model: the Weather Research and Forecasting Model. This ensemble is applied to detect the signs of change in local precipitation in the near future (2012 -2050) under the A2 scenario of climate change. All this information is incorporated in a bio-economic simulation model of regional livestock. This model, MBBCR has three main components: 1) the probability density functions of precipitation determined, as indicated above, both for the present and the future climatic contexts, 2) the response equations of zonal forage resources to seasonal precipitation, experimentally determined through regression analysis, 3) the predictive algorithms for animal response under pasture systems based on the Australian nutrient requirements for domesticated ruminants. MBBCR allows us to study the effects of current and expected precipitations on the modal system and the more technological system. The main results we draw from all these studies is that precipitation in the region exhibits a high degree of spatial homogeneity but also that global warming generated, since the 1960s, significant changes in the historical patterns of rainfall in consonance with substantive changes in the global mean temperature. In fact, average annual precipitation increased by 28.9% ($p < 0,0001$) in the period 1961-2011 compared to 1860-1960. The signs of climate change in the near future (2012-2050, A2) show the potential of changes in the pattern of annual and seasonal rainfall with a tendency to increase in the summer (+36.3%) and fall (+43.9%) while spring will tend to decrease (-11.2%), with reference to the period 1961 to 2011 ($p < 0,0001$). With this information at hand, the bioeconomic model yields that the system with higher level of technology will support higher mean

production rates (+166% y 255%) and economic performance (+479% y 1077%) than under the current modal system ($p<0,0001$), respectively for both climate scenarios: present and future (2012-2050, A2). The system with higher level of technology manifested a lower level of risk as a probability of 0,03% of present a level of meat production less than 70 kg ha^{-1} $year^{-1}$, where the probability of the modal system to overcome this level was only 1,37%. This difference in probability levels is even more pronounced when we compare with the variability of expected precipitation in the near future under the A2 scenario of climate change. We conclude that the system designed with high degree technology is presented as a technological alternative for livestock systems of this region, with lower risk in their production levels and economic performance, when it was evaluated against the entire current climate variability in the region. It also presents as a systemic strategy to mitigate the negative effects that might manifest the event of global climate change signals for the region under study on the behavior of precipitation.

KEY WORDS: Climate Risk, Economic Risk, Business Agricultural, Semi-Arid Region, Optimal Technology.

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