

# Agricultural Risk Management Using NDVI Pasture Index-Based Insurance for Livestock Producers in South West Buenos Aires Province

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# Background and Objectives

The aim of this paper is to evaluate the out-of-sample performance of the NDVI Index-based Insurance in Bahía Blanca Department of South West Buenos Aires Province, following the methodology developed by MAGyP-WB.

With this in mind, we pursue the following two objectives:

- Calculate the premiums and costs of a proposed Index Insurance  
Analyze the results that would have been obtained in 2008 and 2009 (out-of-sample performance)
- Evaluate the reasonability of the premium payments through a comparison of the frequency and severity of payouts and Livestock reduction and economic losses

# Topics to be developed

- Cattle Production: Risks and coverage options
  - Cattle production in South West of Buenos Aires Province (SWBA)
  - Drought Exposure of Cattle and Pasture Production
  - Insurance for Cattle producers in Argentina
- Pasture Insurance using Satellite-based Remote Sensing Indexes. NDVI Index Insurance in SWBA
- Payouts and Rating Methodology
- Performance of the NDVI-Insurance Out of Sample
- Insurance Payouts and losses suffered by droughts
- Conclusions

# Cattle Production: Risks and coverage options

Location of the Buenos Aires Province, Argentina

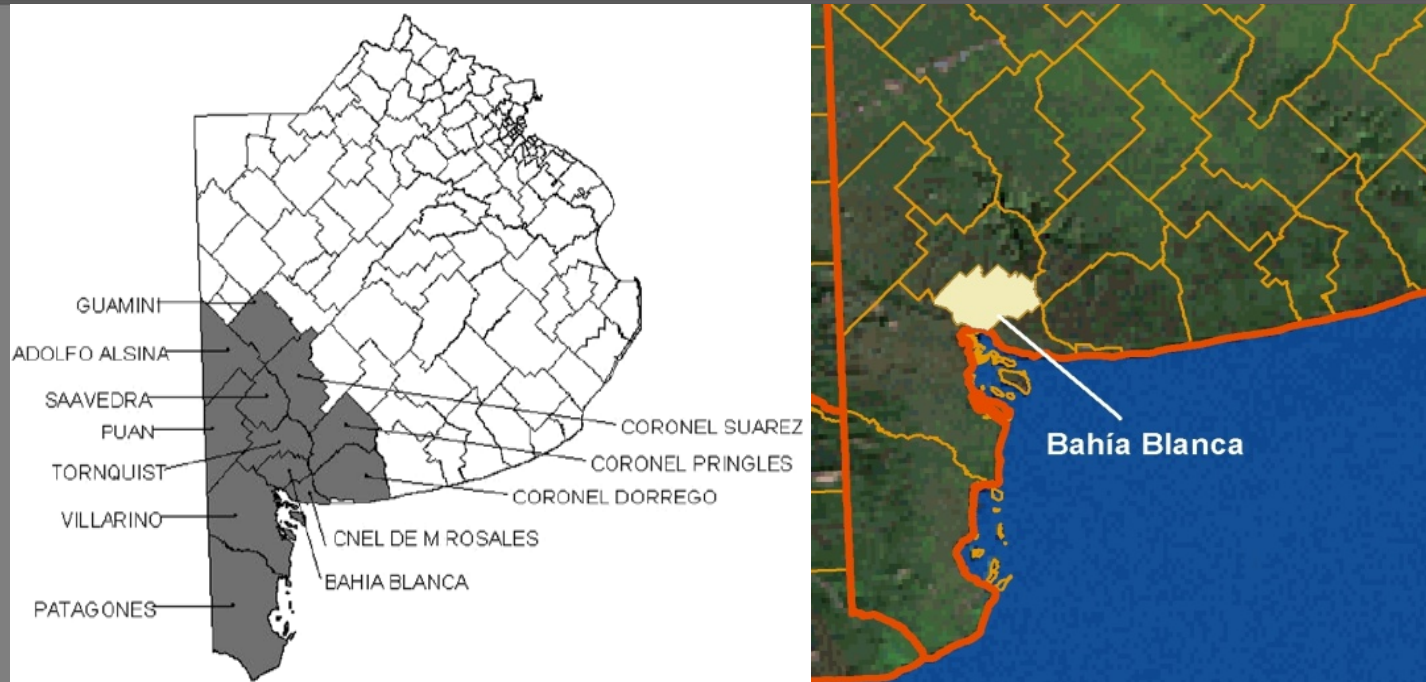


The Buenos Aires Province, located in the Pampas region of Argentina is a significant producer of food, especially grains and livestock

South West of Buenos Aires Province is basically a cattle rearing zone

# Cattle Production: Risks and coverage options

Location SWBA and Bahía Blanca Department, Argentina

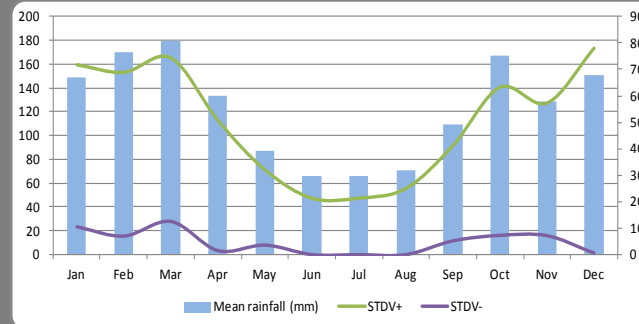
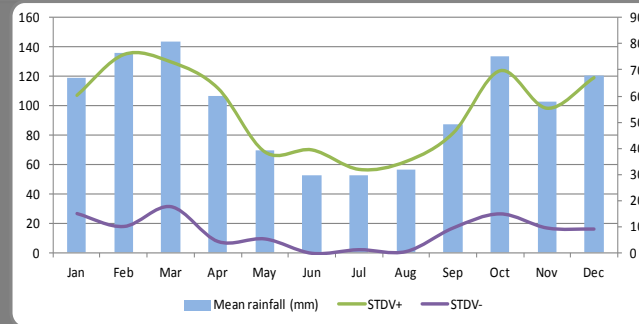
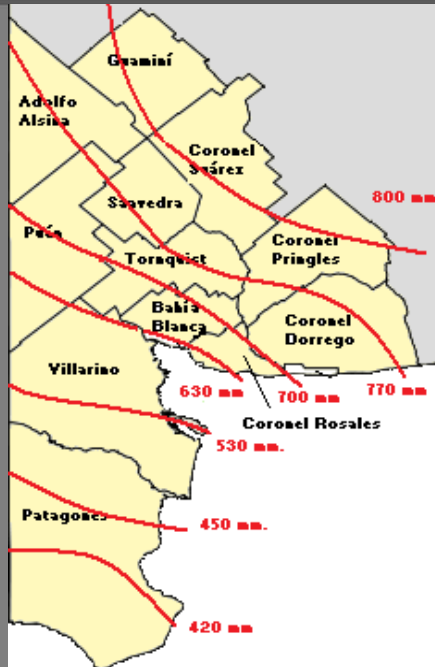


The region has an approximate area of 6,500,000 Ha and includes 12 departments

Cattle production in SWBA is an important economic and social activity and it is based on extensive grazing of natural grassland which is grown under rain fed conditions

# Cattle Production: Risks and coverage options

Rainfall Isohyets (mm) and Climograph Bahia Blanca and Bordenave



The distribution of rainfall over the year presents two peaks, one during autumn and the other during the spring and early summer

According to the weather pattern, cattle production in SWBA is closely synchronized with the agro-climatic seasons in order to match the nutritional requirements with periods of peak pasture production

# Cattle Production: Risks and coverage options

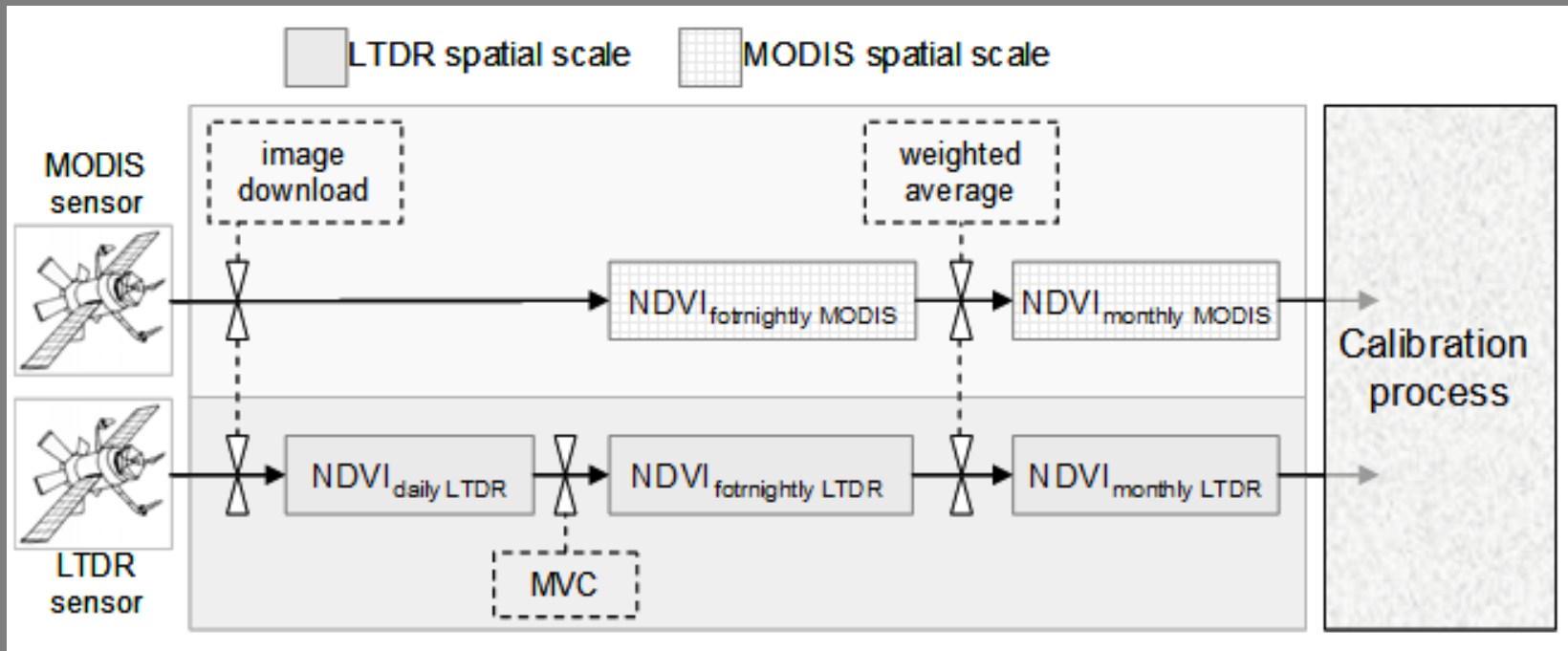
Average annual rainfall is low in SWBA and agricultural crop and livestock production is very exposed to drought

Weak or moderate droughts have been recorded in this region in 9 years in the period from 1982 to date

The lack of a coverage option impacted in cattle production business seen that the livestock insurance market is almost nonexistent in Argentina

# NDVI Index Insurance in SWBA

Based on satellite imagery to measure the Normalized Difference Vegetative Index (NDVI), a coverage option was developed by the Ministry of Agriculture, Livestock and Fisheries of Argentina (MAGyP) with technical assistance of the World Bank (WB) to provide insurance against production losses in pasture

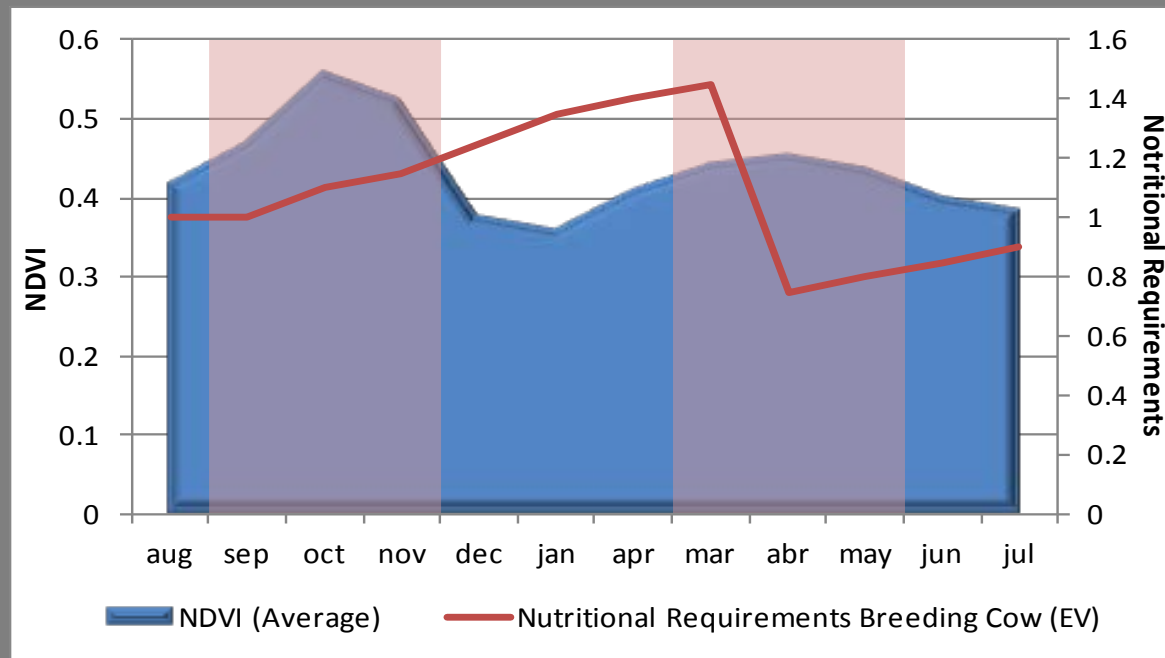


Schematic representation of the procedure followed to obtain monthly values derived from two satellite platforms with different characteristics



# NDVI Index Insurance in SWBA

Two cover periods were selected for the NDVI pasture Index insurance product. They were timed to coincide with peak periods of rainfall and pasture production in the region namely in spring (September to November) and again in autumn (March to May) and to synchronize with calving and nutrition needs in winter respectively



Nutritional requirements and NDVI average corresponds to Cuartel N° 23, Bahía Blanca  
NDVI Pasture Index Insurance Cover Periods are shadowed

# NDVI Index Insurance in SWBA

As the primary objective of the NDVI-based insurance was to protect the breeding animals (cows and heifers) in the event of severe drought induced pasture and fodder shortages, the basis of valuation and the sum insured was determined according to their nutritional requirements during the insurance cover period.

|   |  | Feed based on Maize |                |               |      |      |      |         |      |      |      |      |      |
|---|--|---------------------|----------------|---------------|------|------|------|---------|------|------|------|------|------|
|   |  | E.V.<br>per Ton     | ARS<br>per Ton | ARS<br>per EV |      |      |      |         |      |      |      |      |      |
|   |  | 170                 | 1.400,00       | 8,24          |      |      |      |         |      |      |      |      |      |
| Nutritional Requirements                |  | Calving             |                |               |      |      |      | Weaning |      |      |      |      |      |
|   |  | Aug                 | Sep            | Oct           | Nov  | Dec  | Jan  | Feb     | Mar  | Apr  | May  | Jun  | Jul  |
| E.V. per Cow                            |  | 1,00                | 1,00           | 1,10          | 1,15 | 1,25 | 1,35 | 1,40    | 1,45 | 0,75 | 0,80 | 0,85 | 0,90 |
| E.V. per Heifer                         |  | 0,81                | 0,81           | 0,81          | 0,81 | 0,81 | 0,81 | 0,81    | 0,81 | 0,81 | 0,81 | 0,81 | 0,81 |
| % of Cost of Feed Insured               |  | 0%                  | 50%            | 50%           | 50%  | 0%   | 0%   | 0%      | 50%  | 50%  | 50%  | 0%   | 0%   |
| Sum Insured: ARS per day per cow        |  | 0,00                | 4,12           | 4,53          | 4,74 | 0,00 | 0,00 | 0,00    | 5,97 | 3,09 | 3,29 | 0,00 | 0,00 |
| Sum Insured: ARS per day per heifer     |  | 0,00                | 3,34           | 3,34          | 3,34 | 0,00 | 0,00 | 0,00    | 3,34 | 3,34 | 3,34 | 0,00 | 0,00 |
| Covered days in the month               |  | 31                  | 30             | 31            | 30   | 31   | 31   | 28      | 31   | 30   | 31   | 30   | 31   |
|   |  | Cows                | Heifers        |               |      |      |      |         |      |      |      |      |      |
| Total Annual Sum Insured per animal     |  | 785,85              | 610,36         |               |      |      |      |         |      |      |      |      |      |
| Number of Animals Insured               |  | 31.107              | 15.347         |               |      |      |      |         |      |      |      |      |      |
| Total Annual Sum Insured (ARS millions) |  | 24,45               | 9,37           |               |      |      |      |         |      |      |      |      |      |

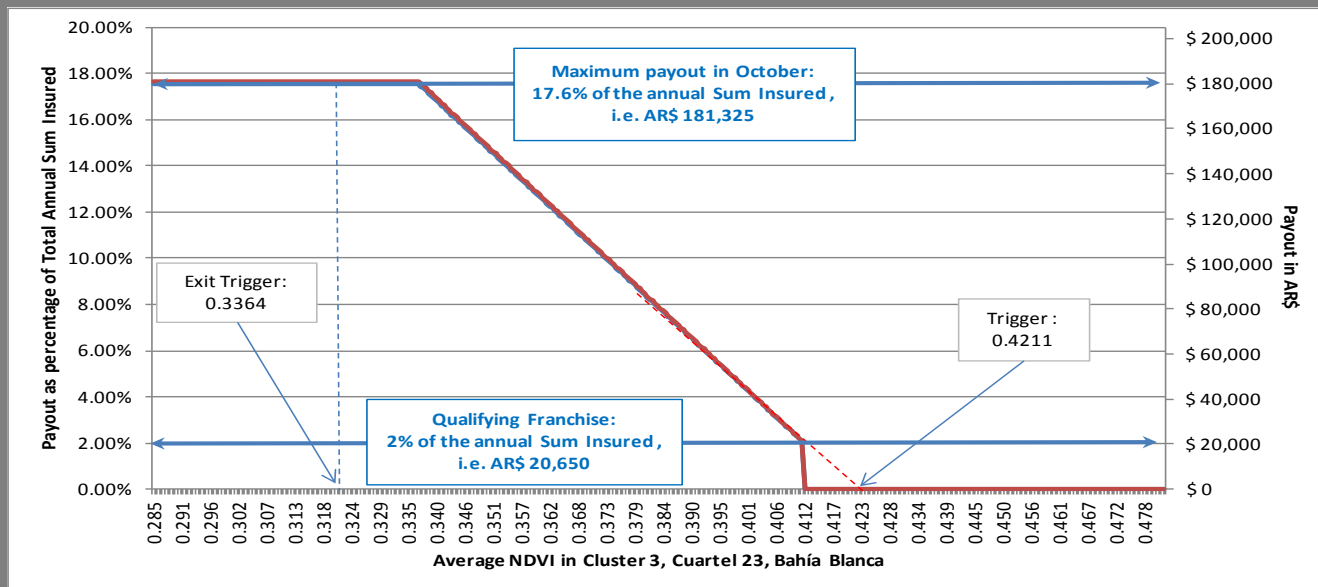
## Calculation of the Sum Insured

Note: It is assumed that cows and heifers in Bahía Blanca at 2014 are insured and the nutritional requirements are covered with maize (approximate price in 2014 is ARS 1,400 per Ton).

# Payouts and Rating Methodology

The Following Figure illustrates the payout rule for an Insured Unit of Bahía Blanca in October with a “non-deductible” franchise: in case the loss is greater than the franchise, the full loss is paid out.

The Trigger Index was set according to a recurrence of 10 years any month in the cover period, and for the Exit Trigger was used a recurrence of 40 years any month.



Example of the NDVI Pasture Index Payout structure for Cuartel 22, Bahia Blanca Department for the month of October

# Payouts and Rating Methodology

The Following Table presents a summary of the pure premium rates at Insured Unit -level and the total. In addition, it is exhibited the calculation of technical and indicative commercial premium rates.

The table also shows the number of Cows and Heifers by Insured Unit at March 2014, and the corresponding Sum Insured, which in turn are used to calculate the Pure Premiums and Technical Premiums expressed in Argentine Pesos.

| Cuartel      | # Pixels  | Pure Risk Rate (%) | Technical Premium (%) <sup>(1)</sup> | Commercial Premium (%) <sup>(1)(2)</sup> | # Cows        | # Heifers     | Total Sum Insured    | Pure Premium (ARS)  | Technical Premium (ARS) <sup>(1)</sup> |
|--------------|-----------|--------------------|--------------------------------------|--|---------------|---------------|----------------------|---------------------|--|
| 18           | 2         | 6.59%              | 8.63%                                | <b>9.50%</b>                             | <b>281</b>    | <b>302</b>    | <b>\$ 404,997</b>    | \$ 26,676           | \$ 34,970                              |
| 19           | 25        | 7.53%              | 10.12%                               | <b>11.13%</b>                            | <b>6,191</b>  | <b>4,019</b>  | <b>\$ 7,317,764</b>  | \$ 550,716          | \$ 740,330                             |
| 20           | 22        | 6.60%              | 8.54%                                | <b>9.39%</b>                             | <b>12,664</b> | <b>5,048</b>  | <b>\$ 13,032,723</b> | \$ 860,042          | \$ 1,112,445                           |
| 21           | 12        | 6.73%              | 8.68%                                | <b>9.55%</b>                             | <b>6,912</b>  | <b>3,036</b>  | <b>\$ 7,284,656</b>  | \$ 490,295          | \$ 632,246                             |
| 22           | 5         | 6.79%              | 8.55%                                | <b>9.40%</b>                             | <b>2,130</b>  | <b>2,040</b>  | <b>\$ 2,919,065</b>  | \$ 198,303          | \$ 249,434                             |
| 23           | 5         | 7.30%              | 9.41%                                | <b>10.35%</b>                            | <b>2,186</b>  | <b>652</b>    | <b>\$ 2,115,710</b>  | \$ 154,473          | \$ 199,142                             |
| 24           | 4         | 7.36%              | 9.89%                                | <b>10.88%</b>                            | <b>744</b>    | <b>251</b>    | <b>\$ 737,789</b>    | \$ 54,312           | \$ 72,968                              |
| <b>TOTAL</b> | <b>75</b> | <b>6.91%</b>       | <b>8.87%</b>                         | <b>9.76%</b>                             | <b>31,107</b> | <b>15,347</b> | <b>\$ 33,812,704</b> | <b>\$ 2,334,817</b> | <b>\$ 3,000,477</b>                    |

(1) The total considers the diversification effect. The total percentage rate does not equal the weighted average of the Cuartel-level rates. The sum of the Cuartel-level Technical Premiums expressed in ARS do not add up the Total Technical Premium, because the latter includes the benefits from diversification.

(2) A 10.00% gross markup was added to the technical premium.

# Performance of the NDVI-Insurance Out of Sample

An out of sample analysis has been carried out to study how the NDVI-based insurance would have worked in the past.

Specifically, it has been taken the data until 2006 to set the Triggers and Exits values and to calculate the premium rates, and the payout and loss ratio in 2007 was then analyzed.

A similar analysis was done for years 2007-2008 and 2008-2009.

# Performance of the NDVI-Insurance Out of Sample

## Case 1:

The triggers were set using the sample from 1982 to 2006 and the rating was performed using this information. The premium rates estimated are lower than the insurance with full sample because the 2008 and 2009 are not included (years with severe drought).

2007 was a normal year in terms of rainfall, and therefore the NDVI-based insurance would have not paid out at all (see last columns).

| Cuartel      | # Pixels  | Pure Risk Rate (%) | Technical Premium (%) <sup>(1)</sup> | Commercial Premium (%) <sup>(1) (2)</sup> | # Cows        | # Heifers     | Total Sum Insured    | Pure Premium (ARS)  | Technical Premium (ARS) <sup>(1)</sup> | Payout 2007  | Loss Ratio (over Comm Premium) |
|--------------|-----------|--------------------|--------------------------------------|---|---------------|---------------|----------------------|---------------------|--|--------------|--------------------------------|
| 18           | 2         | 6,26%              | 8,16%                                | <b>8,98%</b>                              | 330           | 307           | \$ 446.478           | \$ 27.939           | \$ 36.447                              | 0,00%        | 0,00%                          |
| 19           | 25        | 5,99%              | 7,99%                                | <b>8,79%</b>                              | 7.260         | 4.091         | \$ 8.202.625         | \$ 491.007          | \$ 655.410                             | 0,00%        | 0,00%                          |
| 20           | 22        | 6,48%              | 8,63%                                | <b>9,49%</b>                              | 14.852        | 5.139         | \$ 14.807.867        | \$ 959.528          | \$ 1.278.098                           | 0,00%        | 0,00%                          |
| 21           | 12        | 6,65%              | 8,72%                                | <b>9,60%</b>                              | 8.106         | 3.091         | \$ 8.256.585         | \$ 549.240          | \$ 720.275                             | 0,00%        | 0,00%                          |
| 22           | 5         | 7,31%              | 9,24%                                | <b>10,17%</b>                             | 2.498         | 2.077         | \$ 3.230.766         | \$ 236.067          | \$ 298.584                             | 0,00%        | 0,00%                          |
| 23           | 5         | 6,97%              | 8,84%                                | <b>9,73%</b>                              | 2.563         | 664           | \$ 2.419.685         | \$ 168.611          | \$ 213.974                             | 0,00%        | 0,00%                          |
| 24           | 4         | 6,41%              | 8,41%                                | <b>9,25%</b>                              | 873           | 255           | \$ 841.573           | \$ 53.954           | \$ 70.789                              | 0,00%        | 0,00%                          |
| <b>TOTAL</b> | <b>75</b> | <b>6,51%</b>       | <b>8,47%</b>                         | <b>9,32%</b>                              | <b>36.482</b> | <b>15.624</b> | <b>\$ 38.205.579</b> | <b>\$ 2.486.346</b> | <b>\$ 3.236.747</b>                    | <b>0,00%</b> | <b>0,0%</b>                    |

(1) The total considers the diversification effect. The total percentage rate does not equal the weighted average of the Cuartel-level rates. The sum of the Cuartel-level Technical Premiums expressed in ARS do not add up the Total Technical Premium, because the latter includes the benefits from diversification.

(2) A 10.00% gross markup was added to the technical premium.

Premium Rating until 2006 and performance in 2007.

Note: Number of cows and heifers at March 2006. Sum Insured calculated using cost of feed in 2014.

# Performance of the NDVI-Insurance Out of Sample

## Case 2:

The triggers were set using the sample from 1982 to 2007 and the rating was performed using this information. The premium rates estimated are bit lower than the insurance with full sample because in the sample was added one year, 2007, without payouts

2008 shows large losses due to the drought experienced in the region in that year. The loss ratio amounts more than 479%

| Cuartel      | # Pixels  | Pure Risk Rate (%) | Technical Premium (%) <sup>(1)</sup> | Commercial Premium (%) <sup>(1) (2)</sup> | # Cows        | # Heifers     | Total Sum Insured    | Pure Premium (ARS)  | Technical Premium (ARS) <sup>(1)</sup> | Payout 2008   | Loss Ratio (over Comm Premium) |
|--------------|-----------|--------------------|--------------------------------------|---|---------------|---------------|----------------------|---------------------|--|---------------|--------------------------------|
| 18           | 2         | 6.17%              | 8.06%                                | 8.86%                                     | 358           | 334           | \$ 485,182           | \$ 29,934           | \$ 39,098                              | 43.82%        | 494.31%                        |
| 19           | 25        | 6.06%              | 8.08%                                | 8.89%                                     | 7,890         | 4,446         | \$ 8,913,686         | \$ 539,847          | \$ 720,357                             | 56.71%        | 637.99%                        |
| 20           | 22        | 6.32%              | 8.47%                                | 9.31%                                     | 16,139        | 5,584         | \$ 16,091,515        | \$ 1,017,278        | \$ 1,362,632                           | 46.46%        | 498.72%                        |
| 21           | 12        | 6.64%              | 8.70%                                | 9.57%                                     | 8,809         | 3,359         | \$ 8,972,323         | \$ 595,705          | \$ 780,280                             | 31.88%        | 333.30%                        |
| 22           | 5         | 7.23%              | 9.15%                                | 10.07%                                    | 2,715         | 2,257         | \$ 3,510,831         | \$ 253,835          | \$ 321,398                             | 41.45%        | 411.63%                        |
| 23           | 5         | 6.92%              | 8.81%                                | 9.69%                                     | 2,786         | 721           | \$ 2,629,440         | \$ 182,035          | \$ 231,537                             | 41.13%        | 424.61%                        |
| 24           | 4         | 6.35%              | 8.36%                                | 9.20%                                     | 948           | 278           | \$ 914,526           | \$ 58,098           | \$ 76,459                              | 27.47%        | 298.68%                        |
| <b>TOTAL</b> | <b>75</b> | <b>6.45%</b>       | <b>8.42%</b>                         | <b>9.26%</b>                              | <b>39,644</b> | <b>16,978</b> | <b>\$ 41,517,503</b> | <b>\$ 2,676,731</b> | <b>\$ 3,493,898</b>                    | <b>44.37%</b> | <b>479.4%</b>                  |

(1) The total considers the diversification effect. The total percentage rate does not equal the weighted average of the Cuartel-level rates. The sum of the Cuartel-level Technical Premiums expressed in ARS do not add up the Total Technical Premium, because the latter includes the benefits from diversification.

(2) A 10.00% gross markup was added to the technical premium.

Premium Rating until 2007 and performance in 2008.

Note: Number of cows and heifers at March 2007. Sum Insured calculated using cost of feed in 2014.

# Performance of the NDVI-Insurance Out of Sample

## Case 3:

The triggers were set using the sample from 1982 to 2008 and the rating was performed using this information. The premium rates estimated were upward adjusted in comparison with Case 2 because the drought in the added year.

Drought continued in 2009 and low NDVI values observed this year are consistent with high losses. The loss ratio amounts 576%

| Cuartel      | # Pixels  | Pure Risk Rate (%) | Technical Premium (%) <sup>(1)</sup> | Commercial Premium (%) <sup>(1) (2)</sup> | # Cows        | # Heifers     | Total Sum Insured    | Pure Premium (ARS)  | Technical Premium (ARS) <sup>(1)</sup> | Payout 2009   | Loss Ratio (over Comm Premium) |
|--------------|-----------|--------------------|--------------------------------------|---|---------------|---------------|----------------------|---------------------|--|---------------|--------------------------------|
| 18           | 2         | 7.09%              | 9.11%                                | 10.02%                                    | 337           | 314           | \$ 456,112           | \$ 32,352           | \$ 41,561                              | 56.55%        | 564.14%                        |
| 19           | 25        | 6.91%              | 9.08%                                | 9.98%                                     | 7,417         | 4,179         | \$ 8,379,603         | \$ 578,846          | \$ 760,634                             | 85.46%        | 855.90%                        |
| 20           | 22        | 6.95%              | 9.08%                                | 9.99%                                     | 15,172        | 5,250         | \$ 15,127,357        | \$ 1,051,830        | \$ 1,373,540                           | 45.43%        | 454.88%                        |
| 21           | 12        | 6.72%              | 8.70%                                | 9.57%                                     | 8,281         | 3,158         | \$ 8,434,727         | \$ 566,459          | \$ 733,645                             | 47.12%        | 492.54%                        |
| 22           | 5         | 7.56%              | 9.49%                                | 10.44%                                    | 2,552         | 2,122         | \$ 3,300,472         | \$ 249,394          | \$ 313,192                             | 49.43%        | 473.51%                        |
| 23           | 5         | 7.32%              | 9.26%                                | 10.19%                                    | 2,619         | 678           | \$ 2,471,891         | \$ 180,988          | \$ 228,946                             | 62.68%        | 615.27%                        |
| 24           | 4         | 6.75%              | 8.74%                                | 9.61%                                     | 891           | 261           | \$ 859,730           | \$ 58,040           | \$ 75,114                              | 71.84%        | 747.46%                        |
| <b>TOTAL</b> | <b>75</b> | <b>6.96%</b>       | <b>8.94%</b>                         | <b>9.84%</b>                              | <b>37,269</b> | <b>15,961</b> | <b>\$ 39,029,890</b> | <b>\$ 2,717,909</b> | <b>\$ 3,490,068</b>                    | <b>56.71%</b> | <b>576.5%</b>                  |

(1) The total considers the diversification effect. The total percentage rate does not equal the weighted average of the Cuartel-level rates. The sum of the Cuartel-level Technical Premiums expressed in ARS do not add up the Total Technical Premium, because the latter includes the benefits from diversification.

(2) A 10.00% gross markup was added to the technical premium.

Premium Rating until 2008 and performance in 2009.

Note: Number of cows and heifers at March 2008. Sum Insured calculated using cost of feed in 2014.

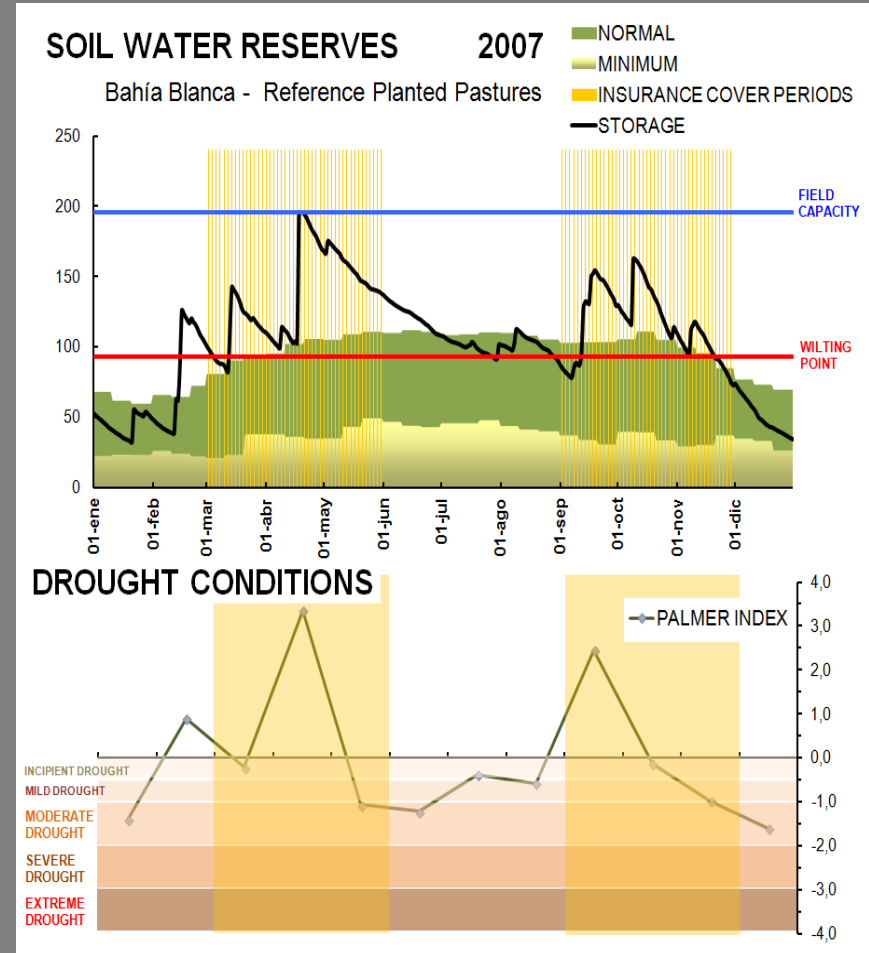


# Insurance Payouts and losses suffered by droughts

The year 2007 has performed well in terms of rainfall, and this is reflected in the Palmer and water balance indexes shown.

While the final months of both cover periods (shadowed in Figure) show a worsening drought conditions, it can be seen that the water storage exceeds average or normal values for the area.

The NDVI index captures the availability of forage resources and as it was expected, the insurance did not trigger any payout in the Insured Units of Bahía Blanca.

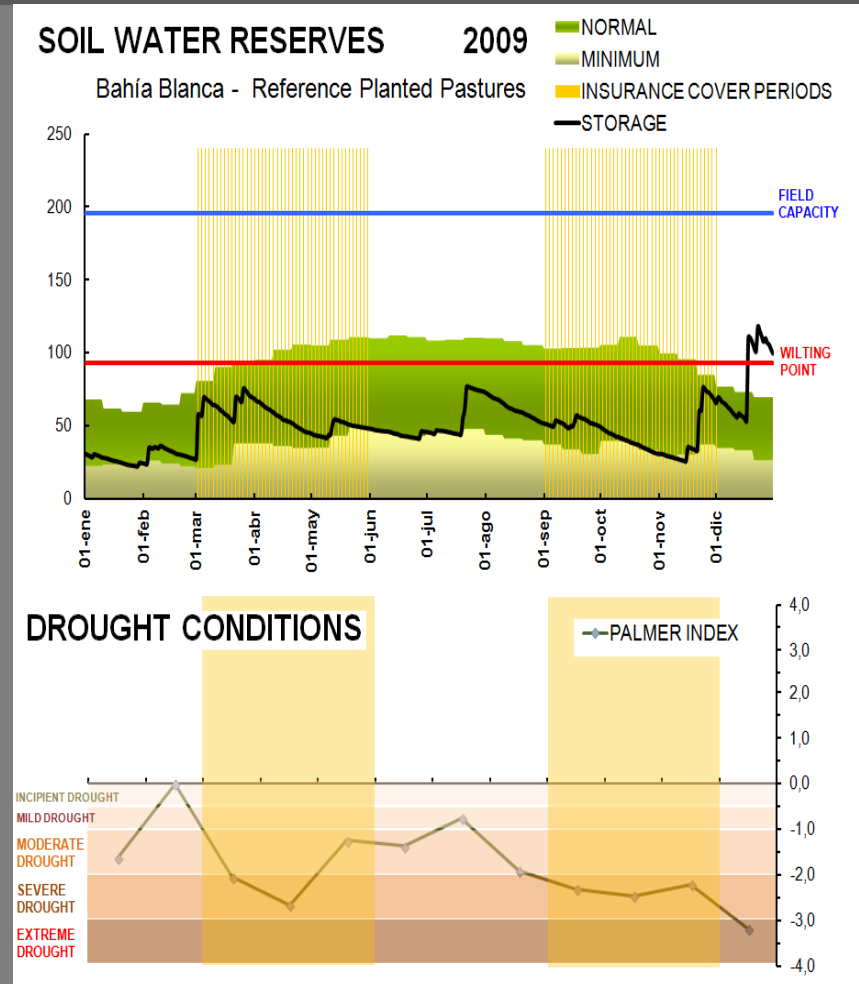


Soil water reserves and drought conditions  
In 2007 in Bahía Blanca

# Insurance Payouts and losses suffered by droughts

Throughout 2008-2009 period, NDVI values were significantly lower, which is consistent with drought conditions reflected by the Palmer and water balance indexes.

Theoretical payouts of the NDVI-based insurance are substantial in this two-year period

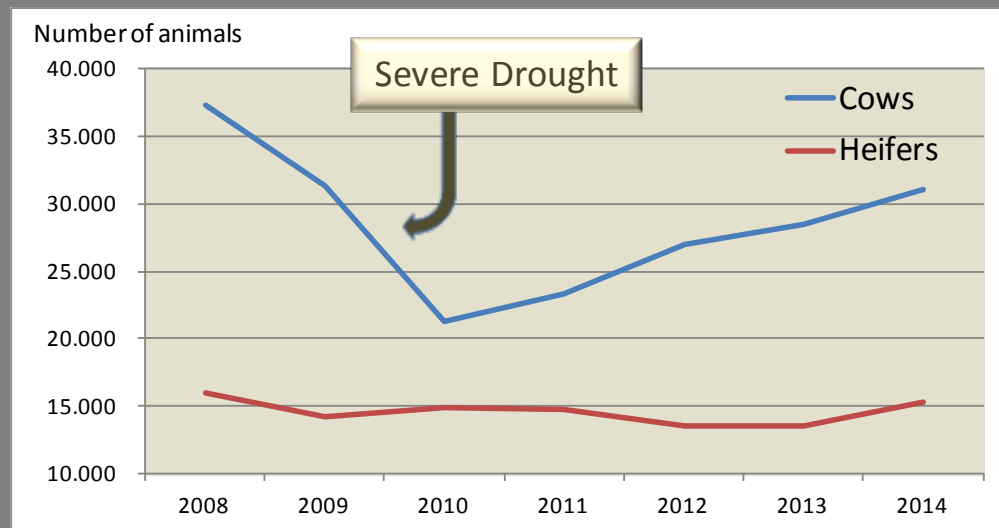


Soil water reserves and drought conditions in 2007 in Bahía Blanca

# Insurance Payouts and losses suffered by droughts

The number of cows and heifers for Bahía Blanca decreased 17,000 animals from 2007 to 2009, with a fall of 14% in 2008 and 20 % in 2009

The replacement cost of the cows and heifers liquidated in 2008 and 2009, measured in current values, amounts approximately AR\$ 27 and AR\$ 30 million, respectively



Evolution of the number of cows and heifers in Bahía Blanca from 2008 to 2014

# Conclusions

Based on the rating methodology described in this paper, payouts determined by the NDVI Index-based Insurance fit with falls in forage production and reduced meat production yields, which confers reasonability to this tool as a coverage option for cattle and fodder producers.

Definite technical premiums based on 1982-2007 period, capture the occurrence of drought events, defining a risk profile that is consistent with the used information. Adding more observations to the sample, this profile is redefined, showing the sensitivity of the results to the quality and quantity of data used in the analysis.

# Conclusions

The election of the period to be considered, how to incorporate the changes in the patterns of climate behavior in the medium and long term, etc., will impact on the values of resulting technical premiums.

Therefore, there is a subjective assessment in the determination of the sample and the weighting of this information. In the specific case of this analysis, the fact of not having considered in the sample two extreme years (2008 and 2009) has a concrete implication in the obtained premiums and cost of the insurance.

# Conclusions

Finally, when the costs of drought and the cost of the NDVI Index-based Insurance are analyzed, it is important to take into account some factors and variables such as: Sum insured per animal (linked to the costs of supplementary feeding), degree of coverage (recurrence period), safety margin of the system (in this case, calculated from the standard deviations), amount of lost production (sick, dead, undersold animals, reduction of sales weight) replacement cost of stock, loss of potential output (decline in pregnancy and birth rates), indirect costs in the activity (economic, social, regional), fall in tax revenues and resources for States to mitigate the effects of adverse events.

The election of these will be decisive to assessing the reasonability of the premium payouts and usefulness as a hedging tool.

**Thank you !!**

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