

Closing the technological gap of animal and crop production through technical assistance



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ABSTRACT

Technical assistance is expected to close the gap between actual and potential agricultural production and increase its inter-annual stability. We here hypothesize that its impact may be greater on complex activities, such as livestock production, than on simpler activities, such as soybean production. To our knowledge, this difference has not been quantified. We gathered livestock and soybean production data from the Argentine Pampas, and contrasted the performance of farmers under high level of technical assistance, in the form of professional advice and feedback from other farmers, against the performance of the rest of the political district, which receive much less technical assistance. The difference in productivity and stability between the two types of farmer was much greater for livestock than for crop production. Livestock production was 96% higher and 70% more stable (lower coefficient of variation of annual output) in farms that received more technical assistance than in the rest of the political district. In contrast, soybean production and stability in farms that received more assistance were similar to the rest of the district. If all farms produced at the level of those under more technical assistance, county-level beef production would increase by 74% and require an increase of employment equivalent to 5.6% of the current working population. These results suggest that extension policies in the region should prioritize animal production because of a greater potential to significantly increase production and lower risk.

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1. Introduction

Agricultural production in much of the world is in the hands of family production units, often inherited. Decisions are largely made on the variable experience and judgment of each farmer rather than on scientific criteria (Abdulai and Huffman, 2005; Nuthall, 2012). The fragmentation of decision making at the farm level, the complexity of agricultural systems, and the variability of knowledge among farmers concur to make the adoption of technology highly uneven over time and space (Mueller et al., 2012; Nuthall, 2012).

Farmers may be technically assisted by professionals and colleagues. During the twentieth century, professional advice mediated between farmers and their problems (Lowery, 1957). Promoted by governments and private initiatives, professionals provided direct access to scientific advances (Rivera, 2011; Sunding and Zilberman, 2001). Agronomic expertise became a major vehicle for technology adoption and complemented scientific research (Strauss et al., 1991). In addition, imitation of neighboring farmers is also important for the adoption of technology (Alene and Manyong, 2006; Barao, 1992). In the CREA groups in Argentina, associated farmers combine both

forms of technical assistance: they share a professional advisor and monthly exchange individual experiences (CREA, 2014). In this paper, “technical assistance” refers to these two aspects of the advice process.

The impact of technical assistance on the agricultural production of a region has been studied in different ways (Anderson and Feder, 2007; Jin et al., 2002). Very few studies on the impact of technology adoption contrast regional information about farms with different levels of technical assistance (Douthwaite et al., 2007). Some authors analyzed theoretically the impact of technical assistance and considered possible improvements (Kalirajan and Shand, 2001). Others stressed the role of the organizational and legal framework (Sandall et al., 2011; Trigo and Cap, 2003) or the availability of skilled labor (Musaba, 2010). Some even warned about the need to incorporate the real constraints under which farmers operate (Nuthall, 2012), and others found that the greater the perception of risk in implementing a technology the longer it takes to adopt it (Batz et al., 2003; Sauer and Zilberman, 2012). Finally, other studies have stressed the importance of joint learning or peer to peer extension as a component of technical assistance (Millar and Connell, 2010; Moyo and Hagmann, 2000; Wennink and Heemskerk, 2006). However, the impact of technical assistance on real farms of different degree of complexity is poorly understood.

We hypothesize that the impact of technical assistance should increase with the complexity of agricultural activities. If an activity

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is simple, with few well known variables, the performance of neighboring farmers with different levels of technical assistance will be similar. In this case, farmers without technical assistance get the technology from other sources, such as input suppliers and informal contacts, and thus the technological gap is narrow. In contrast, complex activities, with many interacting nonlinear variables, present more opportunities for making mistakes or missing opportunities during a production cycle. These errors could be avoided if a farmer had technical assistance, and thus the technological gap is wider.

In this study we assessed (1) the impact of technical assistance on the productivity and stability of systems with different complexity, and (2) the county-level consequences of closing the technological gap on beef production, revenue and employment. As a highly complex system, we focused on birth-to-slaughter livestock operation. This activity takes 27 to 40 months, and involves several categories of animals with particular requirements. As a simple system, we focused on glyphosate-resistant soybean crops under low tillage (Qaim and Traxler, 2005). This activity takes just a few months, weed control is eased by crop resistance to herbicides, mineral nutrition is facilitated by the fixation of atmospheric nitrogen, and branching can compensate for management or environmental events.

2. Materials and methods

2.1. Study region

The central part of the study was carried out using information from General La Madrid County, Buenos Aires, Argentina, which covers an area of 481,000 ha, (Pacín and Oesterheld, 2014; SAGyP-INTA, 1990). It is a vast flat plain between 130 and 200 m.a.s.l. Mean annual rainfall is 800 mm and mean annual temperature is 14 °C. Soils are typical natraquols, alkaline and with poor drainage (lowlands), interspersed with small hills (uplands) with better drained soils (typical argiudols and thapto-argic soils). Lowlands are used for cow–calf operations on natural grasslands and sown pastures. Uplands have been cropped since the beginning of the 20th century (Paruelo et al., 2006) in rotation with sown pastures (Pacín and Oesterheld, 2014).

As cropping is a secondary activity in General La Madrid county, we checked the results on soybean production by performing the same contrasts in Santa Fe Province, where soybean reaches an average 3.4 million ha. Predominant soils are hapludols and argiudols with good cropping aptitude (SAGyP-INTA, 1990).

The farmer groups receiving high level of technical assistance in both regions belong to a non-governmental organization, AACREA (Argentine Association of Regional Consortiums for Agricultural Experimentation). They have regular agronomic advice and a common data recording system (Pacín and Oesterheld, 2014). Farmers meet monthly in groups of 8 to 12 neighbors in order to exchange experiences and share technical advice from a professional adviser who visits each farm at least monthly, serves as coordinator of group activities, and analyzes the physical and economic information generated by the group. Farms that belong to AACREA occupy around 10–12% of the area in both regions. Created in 1957, AACREA quickly spread throughout the Pampa region (CREA, 2014). Farmers who do not belong to AACREA receive in average much less technical assistance in the form of professional advice and peer to peer learning. For example, the largest state-funded extension program with similar characteristics, “Cambio Rural”, assisted 0.4–1.2% of our study areas (INTA, 2010).

2.2. Livestock production

For both the group with more technical assistance (57,000 heads on average) and the county as a whole (437,000 heads on average),

we estimated annual livestock production, the area dedicated to livestock, forage production and the conversion efficiency of forage to secondary production.

Annual livestock production (P) covered the period July 1 to June 30, and was estimated as:

$$P = (O - I + ID)$$

where O and I are livestock output and input, respectively, and ID is the inventory difference during the period (Pacín and Oesterheld, 2014). The AACREA members directly provided the required data for 1998–2010. County-level inputs and outputs for the periods 1998–1999 and 2002–2010 were obtained from SENASA (Argentine National Service of Health and Agrifood Quality), which authorizes, regulates and records livestock transportation. The initial and final inventories were obtained from Fundagla (General La Madrid Foundation for Fighting Foot-and-Mouth Disease), which records twice yearly all animals compulsorily vaccinated against foot-and-mouth disease. As county records are number of livestock classified by age and sex, we assigned a fixed weight per head for each category. The rationale for this assignment was that the slaughter live weight within each category varies by less than 5% (2000–2010 coefficient of variation, Observatorio Bovino, 2014). For 1998–1999, inventory difference was assumed to be nil because vaccination was suspended nationally (the sensibility of including or not this year was below 5% and did not change the conclusions).

Farm-level area assigned to livestock production was reported by each technically assisted farm. County-level area was estimated from a series of consecutive satellite images based on the methodology by Guerschman et al. (2003) for the seasons 2000/2001, 2003/2004, 2006/2007 and 2009/2010. Values for the other seasons were interpolated.

Forage production was estimated by the monitoring service described by Grigera et al. (2007), which is based on remote sensing of absorbed radiation and the radiation use efficiency of forage resources. Forage production was calculated separately for uplands and lowlands. The proportion of each type was provided by each farmer under technical assistance, and by a county-level survey. The resulting proportions were similar: 78.4% of lowland in the group under technical assistance and 79.3% in the other group. Thus, any difference in forage production cannot be attributed to different soil quality between both groups. As these production systems are almost exclusively based on direct grazing, forage is not purchased outside the farm. The small amount of grain used as fodder is produced in-farm and was taken into account in our calculations.

The conversion efficiency of forage into livestock production was calculated as the ratio between livestock production and forage production.

2.3. Soybean production

We compared the average and stability of soybean yields for the 2001–2010 period obtained by the group of farmers under technical assistance and by the rest of the county. As indicated above, we performed the same contrasts for a major soybean production area, the Province of Santa Fe, in the Rolling Pampa. The data on cropped area and yield of the group with technical assistance were taken from the farmers (in the case of Santa Fe from AACREA Statistical Yearbook), whereas county- and province-level data were obtained from SIIA (2010).

2.4. Economic consequences of closing the technological gap

For the period 2002–2010, we calculated the potential beef production of General La Madrid County by assigning the production levels and economic performance of technically assisted farmers to

the rest of farmers. We quantified the invested capital on land and animals for all livestock farmers in the county, extrapolating data from members of CREA groups, which provided the following detailed economic information: Value of initial and final inventory each year, values of all purchased and sold animals and land prize. We estimated the economic performance of farmers with less technical assistance assuming a similar cost structure per unit produced in both groups because the difference in technology is process-based rather than input-based. In addition, increases in variable costs were likely counterbalanced by fixed-cost dilution. The incidence of the cost of technical assistance was only 0.3% total costs. All values were converted to U.S. dollars at the exchange rate of each moment.

2.5. Data analysis

For the first objective, we compared the two types of farmers on the basis of the mean and stability (inverse of the coefficient of variation) of total and per area primary and secondary production. Then, we compared the differences in production and stability attributable to technical assistance between livestock and crop production. Because all the areas were surveyed, there was no need to make statistical inferences about the differences. For the second objective, we estimated the county-level marginal return on capital ratio of the technical assistance: the ratio between the additional gross margin and additional investment for achieving the higher production potential. The gross margin is defined as $GM = O \times (P - UC)$, where GM is Gross Margin (\$), O is Output (kg), P is Prize (\$/kg) and UC is Unit Cost (\$/kg). The productivity of labor with direct employment in beef production was estimated from the relationship between annual production and the number of employees in that activity. As the productivity of labor was independent of total productivity, this constant was used to calculate how many more jobs would be generated by a given increase in production.

3. Results

3.1. Livestock production and technical assistance

On average, livestock production per hectare was nearly twice in farms with high level of technical assistance than in the rest of the farms (Fig. 1). Fluctuations were much less marked in the group with more technical assistance (interannual CV = 7% vs. 23%) and showed an opposite pattern to the rest of the county.

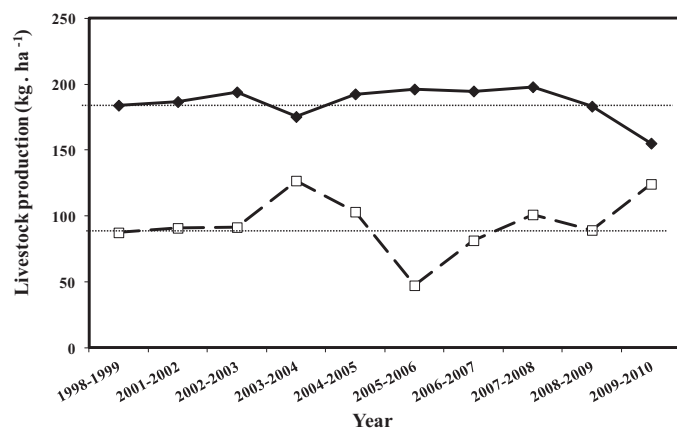


Fig. 1. Livestock production per unit area of two groups of farms with different levels of technical assistance. The solid line corresponds to the group with more technical assistance and the broken line corresponds to the rest of the General La Madrid County. Horizontal lines indicate annual averages of 186 and 94 kg/ha. Notice that the years 1999–2000 and 2000–2001 are missing because of lack of data.

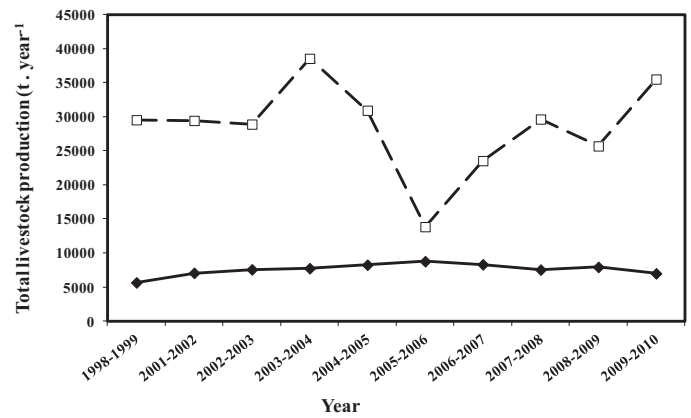


Fig. 2. County-level livestock production of two groups of farms with different levels of technical assistance. Solid line: farms with more technical assistance. Broken line: rest of the General La Madrid County. Notice that years 1999–2000 and 2000–2001 are missing because of lack of data.

Total annual livestock production, which includes possible variations in area dedicated to livestock production, was much more stable in the group with more technical assistance than in the rest of the district (CV = 12% and 22%, respectively, Fig. 2). The larger stability of total livestock production of farms with more technical assistance was accounted for by a larger instability of the area dedicated to livestock. The coefficient of variation of livestock area was 12% for the group with more technical assistance and 6% for the rest. These adjustments of livestock area were done at the expense of crops, which occupied less area in unfavorable years.

The higher livestock production per unit area for the group with more technical assistance may result from higher forage productivity and/or higher forage-to-livestock conversion efficiency. Forage production per hectare was consistently higher in the farms with more technical assistance, both in the poorer, lowland soils (Fig. 3a) and in the richer, upland soils (Fig. 3b). On average, forage productivity in assisted farms was 25% higher than in the rest of the farms on lowlands and 19% in uplands. Forage productivity of the total area dedicated to livestock production was 49% higher in the group with more technical assistance than in the rest of the district (Fig. 3c). The coefficient of variation of forage production was much higher (28%) in the farms with more technical assistance than in the rest (6%). The forage-to-livestock conversion efficiency was on average 21% higher in the farms with more technical assistance than in the rest of the county (Fig. 4).

3.2. Soybean productivity and technical assistance

The difference of soybean productivity between the two groups was much lower than for livestock production (Fig. 5a): average yield was 13% lower in the group with more technical assistance. Stability was also very similar (just 9% higher in the more assisted group). Interannual variations of both groups were nearly synchronous, probably associated with climatic variations. Similar results were found in the much larger cropping area of Santa Fe (Fig. 5b), with minor effects of technical assistance on average yield and stability.

3.3. County-level consequences of closing the beef production gap

County-level beef production would increase by 74% on average if all farmers reached the production levels of the farmers with more technical assistance (Fig. 6). The gap between current and potential production varied inter-annually from a minimum of 21% in

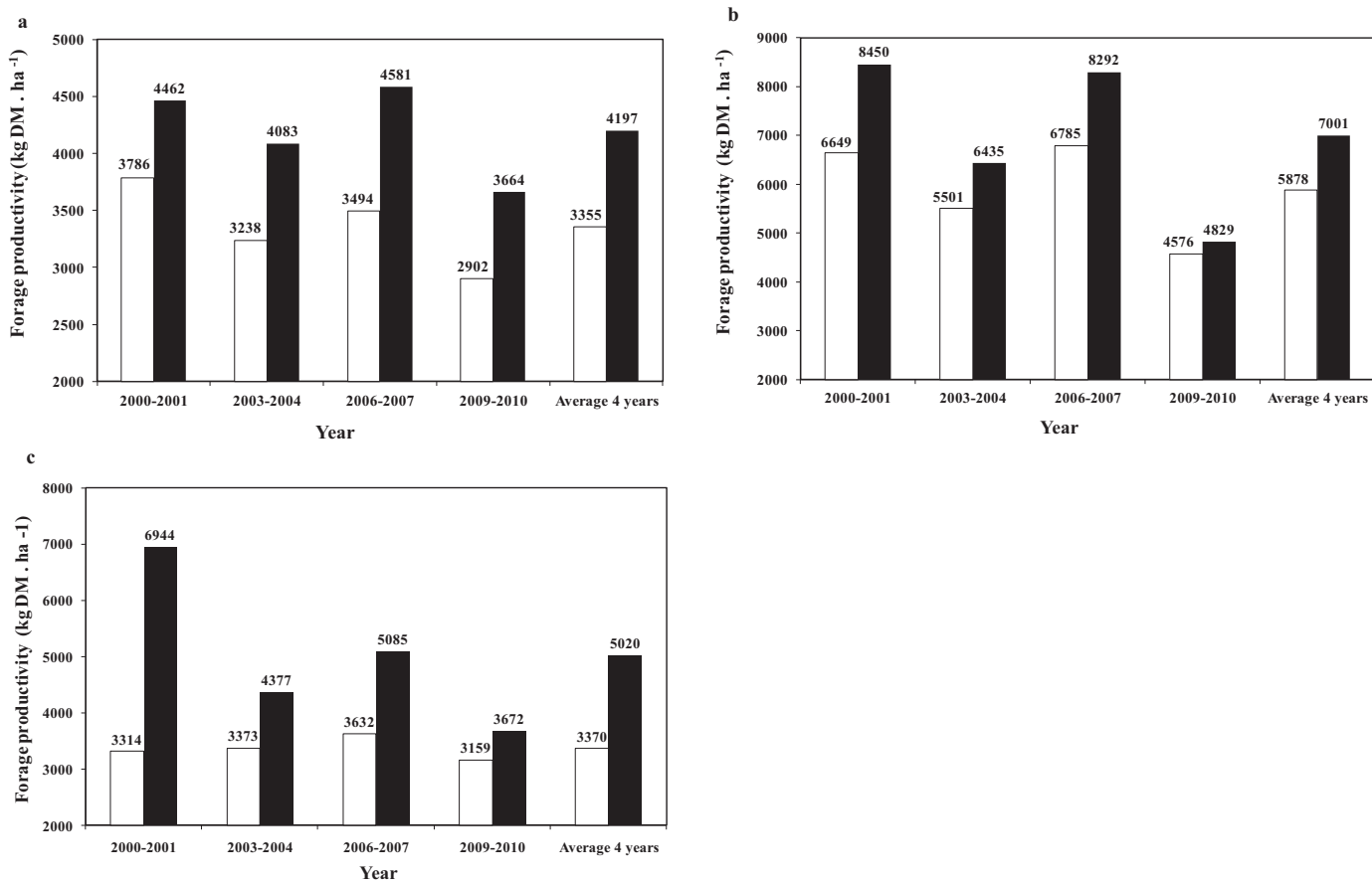


Fig. 3. Forage production of two groups of farms with different levels of technical assistance. Solid bars: farms with more technical assistance. White bars: rest of the General La Madrid County. (a) lowlands, (b) uplands, (c) whole livestock area, which includes crop stubble and annual forages.

Table 1
Real versus potential livestock production value and required capital investment.

	Real production Average 8 years (R)	Potential production Average 8 years (P)	Relative difference (P-R)/R
Livestock production value (\$/ha)	76	132	0.74
Capital invested without land (\$/ha)	222	327	0.47
Total capital invested (\$/ha)	1855	1960	0.06

2009–2010 to a maximum of 193% in 2005–2006. The difference of beef production proportionally translated into an increase of annual production value of 19 million dollars (Table 1). The value gained required a less than proportional increase of capital investment. The annual, county-level average of additional capital needed to reach potential production was 105 \$/ha, whereas the marginal return on capital was 32 \$/ha or 30.5%.

The productivity of labor was 106,265 kg of meat per person per year. Although the variability among farms and years was high, there was no association with total production. Thus, the additional production of meat obtained from reaching the county-level potential (Fig. 6) requires 252 new permanent jobs, which represent a 5.6 point drop of unemployment (County population = 10,783 inhabitants, which based on national averages represent 4450 economically active people, INDEC, 2012).

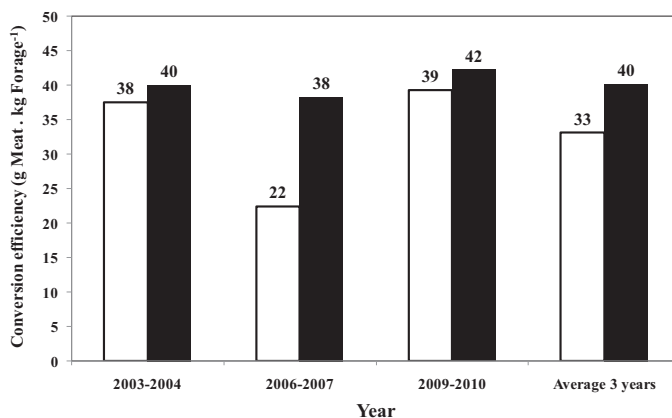


Fig. 4. Forage-to-livestock conversion efficiency of two groups of farms with different levels of technical assistance. Solid bars: farms with more technical assistance. White bars: rest of the General La Madrid County.

4. Discussion

As predicted by our hypothesis, the impact of technical assistance on production and stability was much larger for livestock, more complex, than for soybean (Fig. 7). We found no studies that compare quantitatively the effect of technical assistance on systems of different complexity. Our results suggest that farmers dedicated to

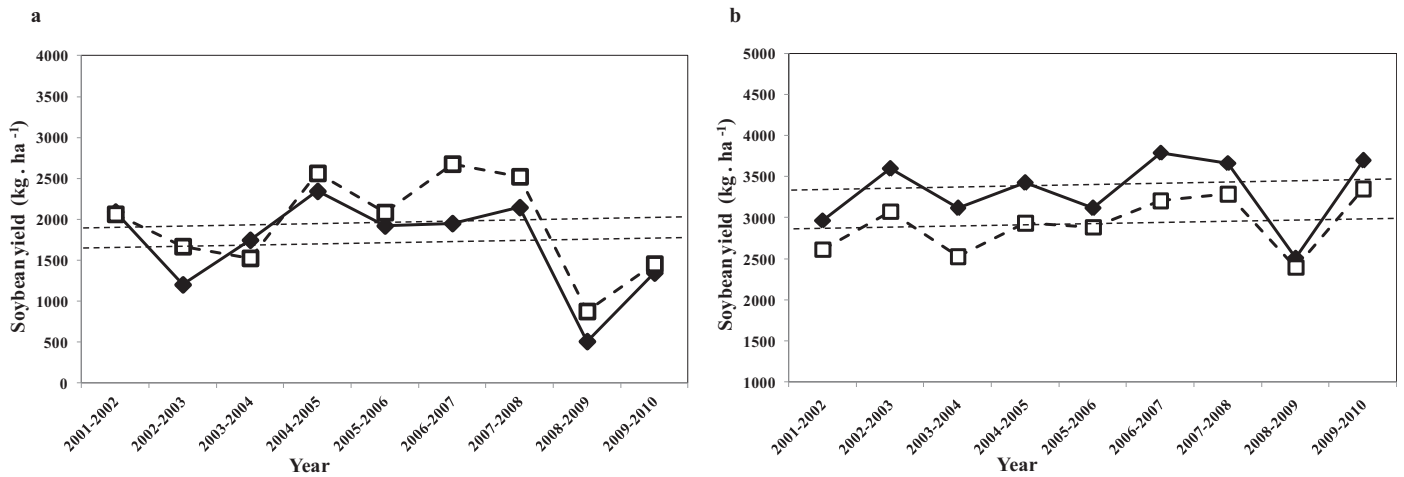


Fig. 5. Average soybean yield as a function of time for farms with different levels of technical assistance. Solid line: farms with more technical assistance. Broken line: rest of the farmers. (a) General La Madrid County. Horizontal lines indicate annual averages of 1696 and 1939 kg/ha respectively. (b) Santa Fe Province. Horizontal lines indicate annual averages of 3325 and 2922 kg/ha respectively.

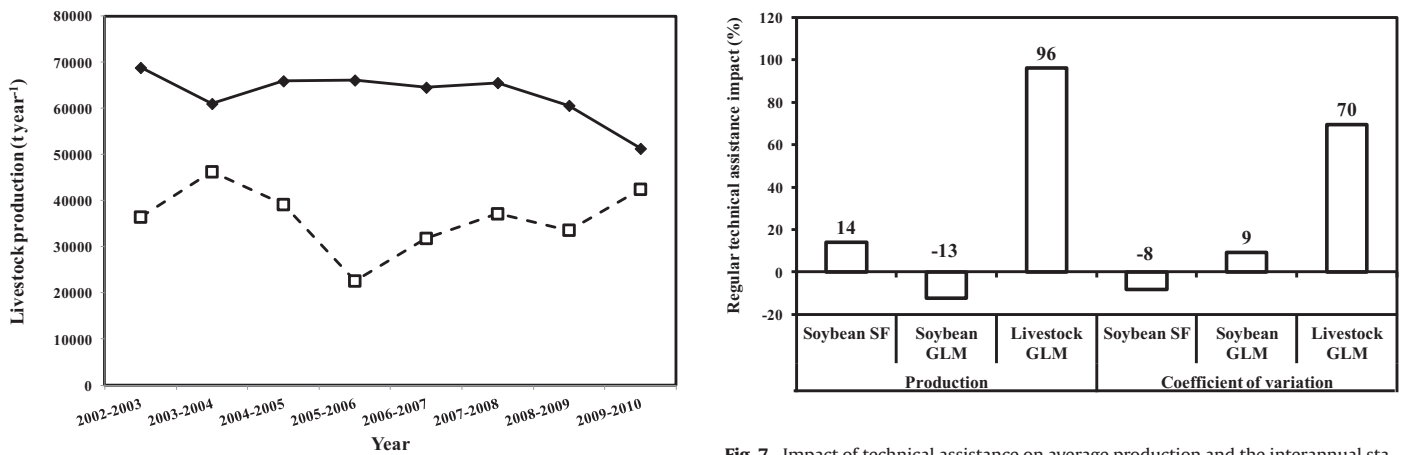


Fig. 6. County-level livestock production in General La Madrid. Solid line: all farmers reach production level of technically assisted farmers. Broken line: observed, current situation.

complex agricultural activities need more technical assistance to successfully implement new technologies than farmers dedicated to less complex systems. Thus policy makers allocating extension resources should take into account this pattern (Jin et al., 2002; Strauss et al., 1991).

What were the major features of technical assistance potentially responsible for the increased productivity and reduced variability of livestock production? First, farms with more technical assistance produced more forage per unit area (Fig. 3), possibly because they included a higher proportion of improved perennial pastures and annual forage crops. Additionally, these forage resources were managed so that a high proportion of solar radiation was intercepted by active leaf area, which was monthly monitored through remote sensing (Grigera et al., 2007).

Second, farms with more technical assistance used the available forage better (Fig. 4), probably because (a) they retained the fattening categories longer than the rest of the farms (the fattening categories are more efficient converting grass into meat than the cow-calf category), and (b) they managed grazing so that bite size was optimized through high instantaneous cattle loads on

high-quality forage. A better management of animal health may have also contributed to increase the conversion of forage into meat.

Third, farms with more technical assistance aimed at a certain level of annual meat production, and consequently strove to hold to that target, even under unfavorable environmental conditions. In the event of harsh conditions (most frequently, dry and cold winters), these farmers incur into the cost of feeding livestock from in-farm crop production and reducing cropping area and so avoid a loss of livestock production and income. As a result, animal production was less variable than in the rest of the farms (Fig. 1), where in the face of the same adversities production and income fell and costs remained fairly constant. Assisted farms must then fine-tune livestock rates so that cost increases do not become too frequent. In this context, forage budgeting is of fundamental importance, which has led to implement sophisticated tools, such as paddock-level forage monitoring through remote sensing (Grigera et al., 2007).

These three groups of technological advances could hardly be implemented by a single farmer. The assistance provided by the professional and by the shared history and feedback of group members help farmers to implement complex activities, such as renewing

Fig. 7. Impact of technical assistance on average production and the interannual stability. SF: Santa Fe province. GLM: General La Madrid county. Impact on production was calculated as the difference of mean production between assisted farmers and the rest of farmers as a proportion of the rest of the farmers. Impact on stability was estimated as the difference of coefficient of variation of production between the rest of farmers and the assisted farmers as a proportion of the former.

perennial pastures, seeding annual forage, adjust grazing so that forage production is high and animal consumption is optimal, manage more demanding animal categories, adjusting disease control, interpreting remote sensing information, and judge the implications of harsh seasons. In contrast, for low tillage glyphosate-resistant soybean, technological advances are generally related to new chemical products or new cultivars, whose advantages are rapidly disseminated among farmers through the publication of simple experiments and commercial messages. These simple technological advances are easier to implement by farmers with less technical assistance.

The impact of technology adoption on productivity found in our study may be compared with findings from other studies, although there are few that account for real, farm-level impacts. Regarding livestock production, we did not find any quantification similar to ours. Neither were we able to find comparisons of real meat production in pasture systems focusing simultaneously on forage productivity and the efficiency of its conversion into meat, as in this study. Regarding crop production, Mueller et al. (2012) found that closing yield gaps so that real yield reaches 100% of attainable yields could increase worldwide crop production by 47% to 71% for most major crops (64% for maize, 71% for wheat, and 47% for rice). Instead, soybean yields in our study were similar between the technically assisted farmers and the rest of the district and were below the theoretical maximum obtainable (Mueller et al., 2012). Rada and Buccola (2012), measuring total factor productivity for crops and livestock in the Brazilian Cerrado, showed large differences between the farms with more and less technological level. The contribution of inputs explained most of the difference, while input use efficiency had a much lower impact. In agreement with our results, farmer surveys in Nebraska showed minor impacts of technical assistance on soybean and corn production (Wortmann et al., 2011).

The economic consequence of filling the gap of almost 19 million American dollars per year represents an increase of 1750 dollars per county inhabitant per year. This is an important amount in a country whose annual per capita GDP was around 10,000 dollars during the studied period (The World Bank, 2013). However, closing this large gap is no easy task. It requires additional capital, human capital, effective government policies, and better extension systems. The required capital is a high proportion of the most labile farm capital, and as a result it may seem unfeasible from the farmer point of view (Table 1). However, it is a minor (6%) proportion if land is taken into account as the farm capital. Because this investment will return 47% higher production value and 43% higher return on capital, farmers might get the extra capital in the financial market or from government sources. In summary, these livestock systems may produce much more with a moderate investment on technology already used by some of their neighbors.

The social impact from implementing technological advances has been insufficiently studied for the agricultural sector (Dries et al., 2012). The most frequently observed trend is that many innovations increase the productivity of labor employed (Pianta, 2005), but have neutral or negative impact on generating direct employment. However, it is not always so. Our results and those by Dries et al. (2012) in the European Union show that the productivity of the workforce employed in pastoral livestock operations is not reduced by the scale of the operation or by land productivity. Thus, in this case technological change may simultaneously benefit businesses, workers and the economy in general. Our results suggest that producing more beef will generate significant economic benefits to the region and also contribute decisively to combat local unemployment. Extensive pastoral livestock is not labor intensive, so neither governments nor communities think of it as a tool to solve unemployment problems. However, we quantified a large potential to generate employment by an activity deeply rooted in local

people. In addition, increasing technical assistance will increase the production of an exportable commodity, with low additional investment and a high return on capital that does not require subsidies from other sectors of the economy.

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