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Feeding the world sustainably: knowledge governance and sustainable agriculture in the Argentine Pampas

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Abstract This article discusses the role of knowledge governance arrangements in the mainstreaming of sustainable practices, in particular, in the creation, sharing and use of integrated and contextualized knowledge. That is, knowledge which accounts for the social, economic, institutional, and ecological dimensions of potentially sustainable practices, and which considers the need to adapt generic practices to the sustainability requirements of specific places. An actor-centered approach is proposed for the study of the historical evolution of knowledge governance arrangements in order to understand their role in the adoption of sustainable practices. The approach is applied to explain the rapid adoption of no-till agriculture in the Argentine Pampas. A radical knowledge governance transformation occurring in this region during the 1990s led to increasing knowledge exchange and pushing sustainability practices to the top of key actors' agendas. This embracing of no-till agriculture illustrates the crucial role played by farmers' associations as boundary organizations: linking farmers with actors specialized in the generation of scientific knowledge and technology. This case reveals that sustainability transitions can be fostered through knowledge governance arenas characterized by: (a) promoting public–private collaboration through boundary organizations, (b) assigning private actors a leading role in the adoption of sustainability practices at the production unit scale, (c) fostering the public sector competence in regional and socio-ecological research, and (d) addressing the heterogeneous needs of knowledge users. However, the case also shows that the success of no-till agriculture in the Pampas is pushing the agriculturization of surrounding areas where this practice is largely unsustainable. This finding suggests that present knowledge governance arrangements fail to contextualize practices that are potentially sustainable.

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1 Introduction

Some of the main icons of industrial agriculture (e.g., mechanical tilling, chemical inputs, and monoculture) are now broadly acknowledged as unsustainable due to their effects on soil degradation and the disruption of ecosystem services (Tegtmeier and Duffy 2004). Mechanized no-till farming, the core practice of the so-called conservation agriculture (Hobbs et al. 2008), is emerging as an economically sound practice that reduces soil erosion and increases fertility (Lal et al. 2007). No-tillage consists of seeding without turning the soil while leaving previous crop residues. This protects against water and wind erosion, increases soil organic matter and water contents, and reduces labor and energy costs (Huggins and Reganold 2008). In addition, the conversion of conventionally tilled agricultural lands to no-till has the potential of reducing carbon emissions (Bernacchi et al. 2006). Despite its clear benefits, no-till farming is not a "sustainability panacea". First, it often leads to increasing reliance on herbicides for weed control. Second, it does not prevent soil degradation unless applied in combination with crop rotations (Reeves 1997). Third, its implementation in vulnerable places not previously used for agriculture, and in the absence of appropriate planning, can generate environmental and social impacts that exceed its potential benefits (Manuel-Navarrete et al. 2009). However, this increasingly popular practice is generally deemed sustainable when applied under adequate circumstances.

This article explores, from the perspective of the study of knowledge systems, the unprecedented rapid adoption of continuous no-till agriculture in Argentina (Fig. 1). This exploration results from 24 in-depth semi-structured interviews with local knowledge actors, an interdisciplinary workshop with 16 local experts, an intersectorial workshop with six high-ranking government officials, bibliographic search, and the analysis of agriculture statistics and censuses. The rate of conversion from plowing to reduced or zero-tillage has been much higher in Argentina than in any other country (with the exception of Uruguay),

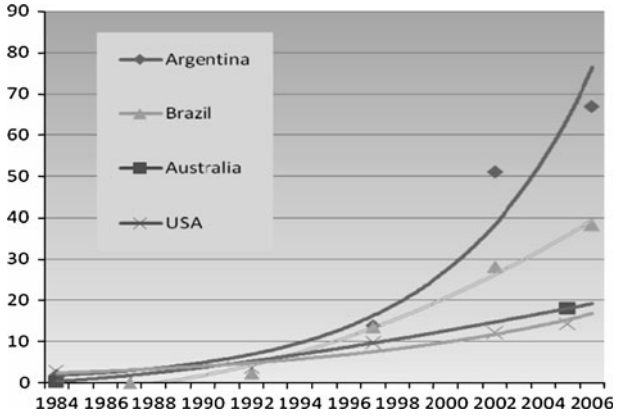

Fig. 1 Trends in the percentage of are cultivated with no-till over total cultivated area (1984–2006). *Source*: AQUASTAT database, FAO

and generally higher in Latin America than in North America, Australia or Europe (Derpsch 2004). Traditional tillage practices started to be seriously questioned as early as in 1945 with the publication of Edward Faulkner's classic book *Plowman's Folly*. In the 1960s, several publications were already reporting on no-till pioneering experiences in the USA (Lal et al. 2007). However, only about 6% of the world's cultivated area is presently farmed under no-tillage (Lal 2009), in stark contrast with the estimated 66% of Argentina's cultivated lands in 2006.

Understanding the processes through which sustainability practices are adopted by users is crucial to foster a global transition toward sustainability. In the case of conservation agriculture, there are place-based factors such as farm sizes, climate patterns, or capital availability, which are likely influencing its adoption. However, this article explores the hypothesis that the success of conservation agriculture in the Argentine Pampas is, to a large extent, explained by the evolution of knowledge governance. Accordingly, it is crucial to understand how the patterns of knowledge governance are affecting the mainstreaming of sustainability practices, as well as integrating the knowledge about their multiple dimensions (e.g., social, cultural, and ecological), and assessing their adaptation to specific contexts. Knowledge governance is not to be understood as static structures, but as fluid and historical processes of co-evolution between agents, organizations and institutional arrangements, and the knowledge they help to create and reproduce (Van Kerkhoff and Lebel 2006).

2 Agriculture development in the Argentine Pampas

The about 50 million ha Pampas ecoregion (North-East of Argentina) (Fig. 2) is one of the six major grain producing agricultural areas of the world. In the 1960s, the region started a slow process of mechanization, crop specialization, and capital concentration. This brought production up, but resulted in soil degradation (Solbrig and Viglizzo 1999). By the late 1980s, erosion had become a serious threat to productivity in those areas characterized by aridity, steep slopes, and thin soils (Casas 1998).

No-till agriculture was popularized in the 1990s, partly in response to the problem of erosion, and rapidly adopted in combination with genetically modified organisms, specifically Monsanto's Roundup-Ready Soy, which is resistant to the herbicide glyphosate (Trigo and Cap 2003). The interviewees agreed that no-till has leaded to significant changes in the governance of farms. In particular, it encouraged the hiring of external services (e.g., sowing, spraying, harvesting, and professional advice), as well as rising the average size of farming operations of already large farms (small farms in the Pampas range from 5 to 200 ha) (Solbrig and Viglizzo 1999).

Conservation agriculture is generally perceived in the Pampas as an economically and environmentally sound practice. Some critics argue that it has boosted glyphosate use, but this has partly been offset by reductions in other, often more harmful, herbicides such as atrazine (Díaz-Zorita 2005). No-tillage is also blamed for destroying rural jobs, but statistics show a historical trend that might have been aggravated, rather than caused, by no-tillage (Manuel-Navarrete et al. 2009). Most informants concur that the major threat of no-till to sustainability is the fact that it makes possible the expansion of the agriculture frontier toward adjacent, highly vulnerable, areas (e.g., dry forest ecosystems and fields cultivated by small farmers) (Morello and Matteucci 1997). In addition, the sustainability of this expansion is contingent on (often cyclic) precipitation patterns.

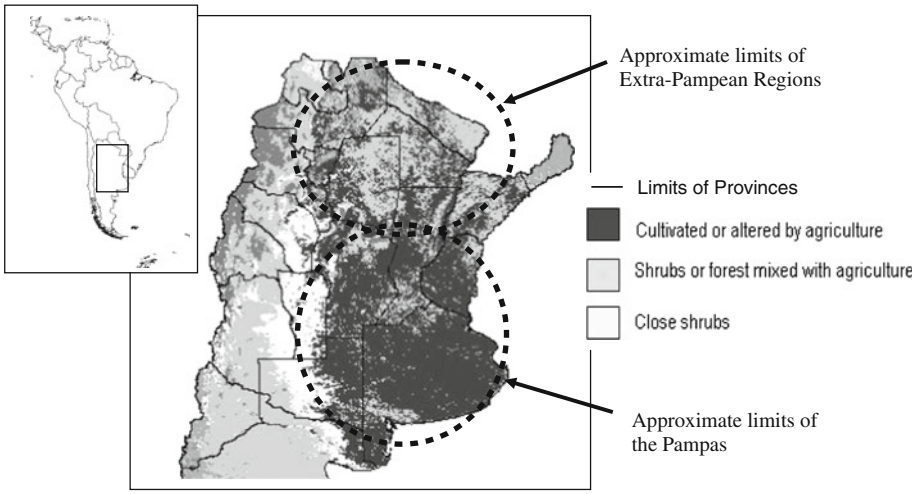

Fig. 2 Location of the Pampas and extra-Pampean regions and land use in Central and Northern Argentina (1990–1996). *Source*: SIGESALC, ECLAC, based on data from the International Geosphere-Biosphere Programme

3 Evolution of knowledge governance in the Pampas

Knowledge governance consists of structures, agents, and cultures shaping the overlapping networks of actors, organizations, and institutional arrangements conducive to the reproduction and transformation of knowledge (Van Kerkhoff and Lebel 2006). In the Pampas, knowledge governance has evolved through two historic phases. The first phase was dominated by the National Institute of Agriculture Technology (INTA), a semi-independent research institute (i.e., tied to priorities dictated by the National Congress, but autonomous in terms of operations and financial management). The second, and current, phase is characterized by the collaboration between public and private actors mediated by farmers' organizations.

Since its creation in 1956, the INTA's network of research stations and extension agencies developed a monopoly of scientific knowledge transfer to farmers (Sábato 1980). This network played a key role in the diffusion of Green Revolution-associated technologies (e.g., mechanization, and the use of fertilizers, pesticides, and hybrid seeds). After the military coup in 1976, the INTA's extension services were hierarchized and segmented, starting a process of deterioration and budgetary cuts (Alemany 2003). Knowledge governance was progressively reduced to the linear transfer of specific technologies to large farmers (Fig. 3). This enabled the unilateral transfer of some breeding improvements (e.g., wheat varieties derived from Mexican germplasm) and crop management (modifications of the environment for enhanced plant growth). However, it failed to suit large producers' demands for knowledge about farming systems (including organizational aspects), agriculture market systems, biotechnology, and process-oriented technologies such as no-till farming (versus input-oriented). Hence, a gap emerged between the INTA and the increasingly complex demands of farmers in a context of growing knowledge commercialization. Simply put, the INTA was unable to provide what farmers were demanding.

In the early knowledge phase, FAO and international NGOs played a guiding role in trying to influence INTA's research agenda and helping to disseminate some innovations

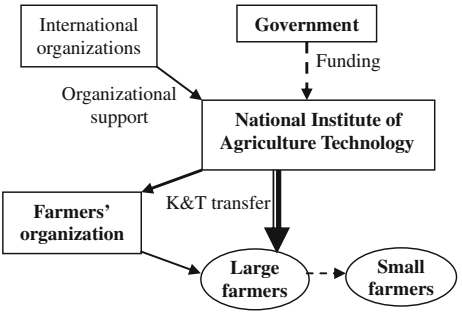

Fig. 3 Knowledge governance in the Pampas (1970s–1980s)

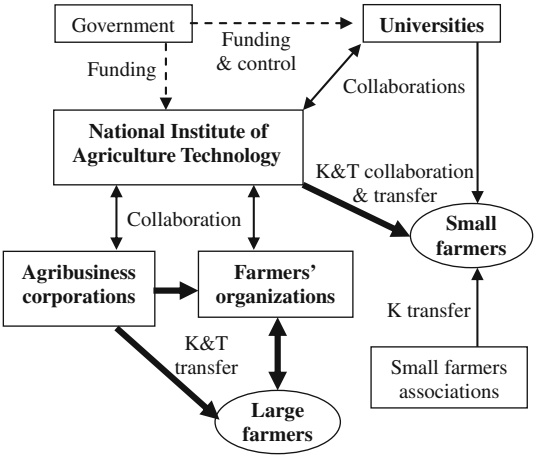

Fig. 4 Knowledge governance in the Pampas (1990s-early 2000s)

related with conservation agriculture (Fig. 3). In 1987, the Latin American Conservation Agriculture Network was created by Argentina, Bolivia, and Paraguay. In 1991, its First Biannual Meeting, organized by the INTA and FAO, took place in Argentina and a handbook about no-till systems for Latin America was published. These early efforts might have paved the way to subsequent diffusion of no-tillage in the Pampas. However, they were not strong enough as to avoid INTA's focus on conventional research approaches (e.g., mechanized tilling, input-oriented technologies, and seed improvement through hybridization), regardless of accumulated evidence of both ecologic and economic unsustainability (Ghersa and Ghersa 1991).

The deregulation and opening to international markets of the Argentine economy during the 1990s reduced even more the government's role in agriculture (Reca and Parellada 2001), and gave way to a new knowledge governance arena (Fig. 4). The governance of knowledge based on INTA's pipe-line model was radically transformed into a network of private agents linked with farmers through farmer's organizations and collaborating with the government as equal partners. In this new knowledge governance arena farmer's organizations, such as the Argentine Association of Regional Consortiums for Agricultural Experimentation (AACREA), which had been secondary in terms of knowledge governance, acquired dominant roles as boundary organizations. AACREA's mission is to create a friendly environment for active thinking, discussion, and exchange of experiences amongst its members. By 2004, AACREA coordinated 136 groups (called CREA groups)

of 8–12 farmers. These groups represented 5–15% of the national crop production and used to obtain superior yields over non-CREA farmers, ranging from 7 to 36%, depending on crop (Gonzalez-Montaner 2004). Superior yields are likely due to CREA farmer's greater innovating efforts. Although representing a small part of the Pampas' farmers, AACREA started to play a critical role in catalyzing innovation at the regional scale. In addition, the Argentine Association of No-till Producers (AAPRESID) was created in 1989 to assist large farmers and technology brokers to exchange knowledge and experiences of no-till system. By 2004, AAPRESID had become a powerful actor with more than 2,000 farmers and 40 associated companies.

Local experts attribute the success of no-tillage to at least four knowledge governance processes. First, the crucial role played by farmers' associations to not only promoting farmer to farmer dissemination, but also filling knowledge gaps between the public sector, large farmers, and international agribusiness corporations (such as machinery manufacturers, biotechnology firms, and chemical corporations producing fertilizers, herbicides, and pesticides). For instance, (Gonzalez-Montaner 2004) describes how AACREA established diverse partnerships with INTA, the National Institute of Agronomic Research of France (INRA), other farmers' organizations, seed companies, and universities for co-producing and adopting knowledge for wheat, corn, soybeans, and sunflower. AACREA is a good example of successful knowledge integration between farmers, private group consultants, and scientists through the creation of a "safe space" for knowledge co-production. The CREA groups (acting at the local level) are the building blocks of the regional groups and these, in turn, constitute the national association. Regional and national coordination of the process of knowledge generation is achieved through the establishment of common protocols and the analysis of major trends. Within each CREA group, farmers contribute with ideas and experience, while a hired technical assistant coordinates and formalizes these contributions and provides technical inputs. Within the organization, formalization is crucial for knowledge sharing and is carried out through writing reports. The role of universities is also important in this formalization. In fact, many of the syntheses and publications of AACREA at the national level are done in collaboration with university teams. However, it is important to note that innovative farmers are the catalyst of the AACREA's system. As described by (Gonzalez-Montaner 2004), CREA members realized that a big part of their innovation has come from trained people looking at the wide variability in field performance arising in response to practices tested and/or varied by farmers.

Second, international corporations established a strong presence, including sales networks providing personalized technical assistance to large farms. For instance, Monsanto played a crucial role through its production of glyphosate in Argentina since 1982. This corporation has actively promoted technological packages combining no-tillage with soybeans resistant to glyphosate and has sponsored research activities with INTA, farmers' organizations, and individual farmers and researchers (Parellada and Ekboir 2003). National agribusiness firms are also progressively joining research efforts in biotechnology (Bisang et al. 2006) and the manufacturing of no-tillage equipment.

Third, large farmers undertook a process of cultural change by progressively transforming traditional family structured production systems into professional agribusiness companies based on entrepreneurial management principles. Interestingly, networking was reported to have become a fundamental part of farming activities, which contributed to speeding up the diffusion of sustainability practices. Innovative farmers started to acquire organizational know-how in areas such as public relations, creating scale economies, adopting new technologies, risk management, total quality management, and

commercialization. Farmers' organizations and corporations promoted this "business culture", which in turn encouraged enlarging the scale of operations and enhancing control over production chains. Developing strong networks with local contractors became a crucial organizational strategy (Parellada and Ekboir 2003). Some landowners even decided to operate their land as agribusiness "franchises".

The fourth crucial process explaining knowledge system effectiveness was the late 1990s INTA's institutional reforms to increase its salience as a knowledge producer (Gutman et al. 2006). These reforms entailed to make extension services more demand-oriented, transparent, and complementary with private research efforts. In addition, more attention was placed over small farmers' needs, poorly attended since the late 1970s. According to interviewees, the INTA undertook a deep reform of its extension services in the light that one-fit-all transmission of research results to "generic farmers" was no longer a sound practice. A strategy based on targeting the particular demands of different types of farmers was initiated in order to deal with the perceived heterogeneity of the agriculture sector. Small farmers' organizations also pushed INTA's reforms by becoming more active in knowledge governance issues. For instance, opposing the patenting of Argentine varieties of seeds, advocating the rights of farmers to use and exchange seeds freely, and increasing their and involvement in technical assistance and training.

In 1993, the INTA launched the Rural Change Program for targeting the specific needs of small and medium farmers (in the Pampas this means 5–500 ha). This program is based on AACREA's organization model. It aims to re-formulate extension as an instrument for strengthening the self-learning capacities of rural communities by stimulating farmer–consultant–scientist interactions. Its objective was to create 1,500 independent groups of less than 16 farmers each (Thornton 2004). As in AACREA, each group chooses a consultant and initiates a process of continuous training both within the group and in collaboration with other groups. Consultants are initially paid by INTA, until the group is able to bear the cost, but are accountable to farmers. By 1999, about 45% of the groups were entirely paying their consultant's wages (Carballo Gonzalez 2002). Rural change is bringing about an extension model based on farmers' organization and public–private partnership. It seeks to improve farmers' competitiveness and self-reliance as the public sector is at the same time decentralized.

The credibility and legitimacy of the scientific knowledge produced by INTA was never at stake. However, INTA's research outcomes became increasingly uninteresting (less salient) amongst large farmers resulting in a gap between the public and private sectors. In order to improve salience and close the public–private gap, the INTA sought to enhance its research capabilities in biotechnology (Gutman et al. 2006), integrated farming systems, and agriculture markets. Another strategy consisted of creating boundary institutions. For instance, ArgenINTA Foundation is a public institution created by the INTA in 1993 to foster public–private collaborations. A public company, Agriculture Technological Innovations, was created in order to attract private funds for developing and commercializing the technologies generated by INTA. This public company integrates farmers' organizations as part of its governing body. It seeks to bridge INTA's products with private demands, create strategies for innovation and market development, promote risk-sharing investments and technology partnerships, and support the INTA's knowledge rights management.

4 No-tillage and knowledge governance for sustainable development

The adoption of no-till agriculture in the Pampas can be characterized as a win–win strategy (i.e., reducing erosion while, at the same time, increasing profitability). In

addition, biotechnology eased weed control and increased, even more, the productivity of no-till techniques. Other contextual factors contributing to its rapid adoption were as follows: (1) a transient lack of legislation protecting intellectual rights over genetically modified organisms, which allowed farmers to use genetically modified seeds for free, (2) favorable international prices of soybeans, and (3) land tenure stability that afforded a relatively safe environment for innovation. These factors probably deserve further examination. However, knowledge governance was particularly important in this case because no-till is a highly complex agriculture system whose adaptation to specific local conditions is not straightforward. For instance, it requires extensive application of agrochemicals, knowledge about favorable climatic conditions, and the building or modification of sophisticated machinery. In addition, the crop residues left on the surface constitute an ecosystem that requires to be managed in terms of nutrients, material flows, and biological processes. Consequently, the active involvement of farmers, their organizations, and other stakeholders in several phases of the knowledge production process is often essential.

A landmark for the adoption of no-till agriculture in the Pampas was the creation of AAPRESID. This organization is accountable to both farmers and agribusiness companies and therefore may be seen as a boundary organization. AAPRESID is also actively collaborating with international corporations, the INTA, and AACREA in research-based endeavors. It provides an good example of an organization purposely set up for promoting learning. AAPRESID embraces sustainable development, system thinking, and knowledge management in its institutional discourse. Its mandate is: "to create an open network of innovating farmers which is receptive to scientific and technological advancements and aims to join knowledge and experience by integrating research, technical assistance, and production". This mandate is executed by organizing fieldtrips, seminars, congresses, technical exchange workshops, and through disseminating essays and publications. Successful stories about no-till management are regularly systematized and made available through AAPRESID networking. Furthermore, AAPRESID is one of the main proponents of the idea of distinguishing between practicing no-tillage as a technique, and adopting a "no-till production system". The latter integrates crop rotation, integrated pest and weed control, and nutrients management. It is often argued by AAPRESID members that a systems approach entails major receptiveness to interrelations. This, in turn, promotes knowledge about the functionality and sustainability of the system as a whole, including environmental impacts.

Sustainability is a central concept in the discourses of the actors promoting no-till systems. Large farmers are usually more concerned about the environmental (i.e., accessing green markets and complying with legislation) and economic aspects of sustainability, while small and medium farmers emphasize the social, cultural, and ecological (i.e., viewing the farm as an organic entity) aspects of sustainability (Craviotti 2002). In both cases, no-till adoption has encouraged the inclusion of sustainability in the farmers' agendas and discourses. However, categories such as "environmentally sensitive large producers" or "ecologically concerned small farmers" need to be treated with caution. On the one hand, the environmental sensitivity of large farmers is always subject to profitability: the resource is conserved in as much as its capacity to produce is maintained in the time frame of private interest. On the other hand, the ecological worldview of small farmers is not widespread in practices; there is potential and a certain level of ecological culture and practices that can be worked on, but small farmers are not in reality, due to various limitations, "ecological" as a rule, and suffer the consequences of their own and other parties' unsustainable practices.

In the Pampas, all farmers tend to associate sustainability with both stability and profitability, which are historically their two major concerns. Through no-till agriculture, many were able to experience how altering some practices may simultaneously improve economic, environmental, and social sustainability. Once broadly adopted, no-till agriculture changed the production paradigm in the region. Arguably, its adoption entailed more than changing cultivation techniques. Rather, it involved deep changes in the organization of production leading to sociocultural changes. More precisely, it brought about the emergence of a knowledge governance characterized by the following: (1) diversifying the scope of scientific knowledge (beyond the traditional agronomic field), (2) encouraging farmer's scientific literacy and the need for external technical advice, (3) increasing concern for the sustainability of farming systems, and (4) articulating discourses based on the notions of knowledge networking. This last point is important because a knowledge exchange culture favors the intensive generation and exchange of knowledge increasing the ability of the knowledge system to adapt to novel challenges. This was evidenced in the interviews by the actors' awareness of future sustainability challenges such as the need to reduce monocropping (regardless of the tillage system), as well as concerns that the intensive use of glyphosate is creating weed resistance to herbicides whose management will require the adoption of precision agriculture techniques.

5 Sustainability knowledge gaps

As discussed above, the evolution of the knowledge governance arena in the 1990s was effective in promoting the rapid adoption of no-till agriculture. However, two significant sustainability knowledge gaps were identified in this case. First and despite the clear benefits of no-tillage, adoption rates among small farms are relatively lower than the rates of adoption at medium and large farms. Census data show that by 2001 only 18% of the 12,309 farms smaller than 25 ha had adopted no-tillage. In contrast, 32% of farms between 25 and 20,000 ha and 52% of the farms larger than 20,000 ha were practicing no-tillage (SAGPyA 2002). This could, in part, be explained by the gap existing between the INTA and small farmers until the late 1990s, as well as by the lack of interest of agribusiness corporations for small and medium farmers. As a result, nobody developed no-till technological packages adapted to the needs of the Pampas small farmers regardless of their eventual willingness to adopt them. Besides this knowledge gap, another limiting factor for adoption amongst small and medium farmers might be the scale at which no-till technology is optimized. However, the process of optimization is not neutral but contingent on the orientation given to previous technological investments, which in this case were decisively oriented toward the needs of large farmers.

The second gap relates to the failure of the current governance regime to produce and use integrated and contextual knowledge for guiding the expansion of agriculture toward socially and environmentally vulnerable areas surrounding the Pampas (Pengue 2005). In fact, the unplanned transference of the Pampas' model toward more fragile ecosystems is catastrophic from ecological and social points of view (e.g., causing biodiversity loss, soil erosion, rural exodus, and conflicts with indigenous populations) (Manuel-Navarrete et al. 2009). Some university groups and NGOs are the main critics of this process. These actors argue that these neighboring areas are under a dangerous situation of violent technological intrusion whose consequences are largely unknown (Pengue 2004). In addition, the advancement of agriculture in many of these areas is only feasible due to a contingent

period of higher rain rates, which started in the 1960s (Viglizzo et al. 1997). The question remains of what will happen if a drier period begins.

Unfortunately, knowledge to ensure ecological and social integrity at a regional scale is not only scarce and incomplete, but also hardly salient amongst farmers due to their customary focus on the farm scale. Not surprisingly, private actors have been inadequate in providing knowledge whose benefits cannot be easily appropriated at the farm level. For instance, integrated and systemic analyses useful for territorial planning, assessment and monitoring of impacts at the regional, ecosystem, and species levels, social science knowledge in general (when not related to business and finances), or critical analyses of the technologies that are strategic to agribusiness corporation (e.g., the effects of genetically modified soybeans and glyphosate on ecosystems). Thus, the customary limitations of privately produced knowledge stress the importance of public actors and central planning (national or provincial) for sustainability in a wider sense than the scale of the farm. Private decisions will optimize, in the best of cases, the use of private land, but to regulate and limit the advance of modern agriculture to areas where such practices are not sustainable requires direct involvement of government and the implementation of integrated policies (Manuel-Navarrete and Gallopin 2007).

Public actors have been reasonably effective in at least producing relatively integrated assessments of the environmental impacts of agriculture (e.g., Viglizzo et al. (2003)). These assessments are useful for raising public attention and moving these issues up in political agendas. However, as pointed out by the authors of these assessments, there are still numerous knowledge holes (Manuel-Navarrete et al. 2009). For instance, on the biophysical side there is significant ignorance regarding the complex relations between nutrient stocks and fluxes (i.e., rates of leaching, run-off, sediment, and volatilization), lack of accurate information on evapotranspiration and water soil retention capacity, lack of precise data on fertilizers use during the 1990s, and no direct field measurements of pesticides impact on biodiversity. Uncertainties surrounding the social impacts of agriculture are not less significant. Furthermore, according to interviewees the current knowledge governance is not efficient in making the results of these assessments readily usable for public, or private, decision making, and planning. For instance, there are few mechanisms for the integration of social, ecological, agronomic, and economic knowledge into action. Therefore, even if some integrated knowledge is produced the mechanisms, or political will, for its effective use are often missing.

As a corollary of the above discussion, further knowledge governance changes will be needed if the gap between "sustainability researchers" and public/private actors is to be bridged. Some interesting initiatives have emerged in this direction with little success so far. For instance, the multilateral "Forum for 100 Million Tons of Sustainable Soya" was launched in 2003 as a space for discussion to engage a diversity of players in the study and negotiation of agriculture expansion. However, after a few gatherings, the initiative was dissolved into oblivion as the private sector, environmental NGOs, government representatives, and scientific-technical institutions were unable to keep a dialogue. At the international scale, similar consensus-based initiatives seem to be more successful in gathering international NGOs, large farmers, and agribusiness corporations under the umbrella of sustainable soy roundtables, task forces, and initiatives for "responsible" soy. The environmental certification of crops has been also experimented as a potential boundary object to close the sustainability knowledge to action gap. For instance, according to interviewees, the ArgenINTA Foundation developed a labeling scheme for certifying agriculture products that comply with good environmental practices, including land selection, seeding process, crop development, harvesting, packaging, and transport.

The idea was that farmers would be interested in certifying their crops in order to comply with exporting standards while adding value to their crops. However, there is no evidence that this initiative is having any significant impact.

6 Conclusions

The case of no-till agriculture in the Argentine Pampas shows the crucial role of knowledge governance to foster the adoption of sustainability-related practices. In the 1990s, knowledge governance in Argentina became more complex and network-like, knowledge exchanges multiplied, and private actors increased their relevance. Such transformation implied moving from vertical knowledge transfer to a more horizontal arena. This might have favored the rapid adoption of win–win options, such as no-till agriculture. Knowledge-related barriers and enablers to the adoption of conservation agriculture might be similar to the barriers and enablers to renewable energies, and other sustainability practices. Future research should focus on comparing the evolution of knowledge governance for the sustainable adoption of sustainability practices across places and sectors in order to reach some level of generalization.

Private actors were particularly effective at producing and using knowledge at the scale of the farming unit. The emergence of new financial and contractual arrangements allowed non-traditional private investors to participate in the agriculture business. Capital availability favors the marketing of agriculture services (including no-tillage seeding) and accelerated the sector's technological and knowledge dynamics and flexibility. Sustainability issues moved up in the agendas of private actors probably because sustainability discourses were perceived as improving economic performance and social acceptability, while at the same securing crop productivity in the long-term. However, these governance arrangements in which large private actors controlled the knowledge agenda tended to marginalize the needs of the least powerful actors (e.g., small farmers). In addition, private sector organizations were unable to produce (1) integrated and regional scale assessments, (2) knowledge about the social systems (other than economic or financial), and (3) critical scrutiny of the technological packages promoted by powerful corporations.

Public actors underwent substantial reforms in order to increase salience amongst large farmers and to close the gap with small and medium farmers. For instance, the INTA espoused demand-oriented strategies and advanced its biotechnological research capacities. These reforms improved knowledge governance, but further changes are needed in order to support small farmers, as well as to generate integrated knowledge that can be effectively used to ensure the sustainability of further agriculture expansion.

Public–private partnerships will continue to be crucial in order to fulfill unmet sustainability knowledge needs. The active participation of farmers in research has shown to enhance knowledge governance and should be further promoted in the future. However, governments have still important roles to play in promoting research that benefit the interests of the least powerful actors in the system. The production and use of knowledge for a sustainability transition requires knowledge co-production and public–private collaboration. Knowledge users are critical for adapting sustainability practices to the contextual singularities of each place. However, global priorities and overall development should be overseen and amended (when needed) by those actors who are capable of looking at the regional socio-ecological system as a whole.

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