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ORIGINAL ARTICLE

Soy production and certification: the case of Argentinean soy-based biodiesel

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Abstract With the rising emphasis on biofuels as a potential solution to climate change, this paper asks whether certification schemes, developed to promote sustainable feedstock production, are able to deliver genuine sustainability benefits. The Round Table on Responsible Soy (RTRS) is a certification scheme that aims to promote responsible soy production through the development of principles and criteria. However, can and does this initiative address the negative impacts associated with the intensive production of soy? Taking the example of soy biodiesel produced in Argentina, this paper asks whether the social and environmental impacts of soybean production can be mitigated by the RTRS. It concludes that at present certification schemes are unlikely to be able to address either the institutional challenges associated with their implementation or the detrimental impacts of the additional demand generated by biofuels.

Keywords Agrochemicals · Argentina · Biodiesel · Certification · Soybean

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1 Introduction

At the dawn of the 21st century, we are faced with three grand challenges: rapidly rising carbon emissions, growing concern about energy security and the elimination of global poverty. Many governments and business have been quick to emphasise the potential benefits of biofuels, on the basis that they provide a carbon neutral means of decarbonising the transport sector. It is also regularly claimed that biofuels may also promote rural development by creating new livelihood opportunities, particularly in developing countries. In the near term, most biofuels will be produced from agricultural crops. Biodiesel is made from vegetable oil crops such as soy (*Glycine max L.*), palm (*Elais guineensis*) or oil seed rape (*Brassicaceae spp.*), whereas bioethanol is based on carbohydrate sources such as sugarcane (*Saccharum officinarum*), maize (*Zea mays*) or wheat (*Triticum aestivum*). In the longer term, so-called second generation biofuels, produced from feedstocks that do not compete with food (e.g. wood, grasses, algae) will meet some of our fuel needs.

Despite receiving substantial global impetus biofuels have rapidly become a contentious energy option. For example, some are concerned that production and trade in biofuels on the scale implied by the EU targets holds the risk of tying energy supply into highly unsustainable agricultural practices. Other risks associated with increased global production and trade in biofuels include direct and indirect land use change (e.g. Searchinger et al. 2008; RFA 2008) and competition with food production (e.g. OFID 2009).

1.1 European Union policy

In 2003, the European Commission (EC) in its Directive ‘on the promotion of the use of biofuels or other renewable fuels for transport’ adopted indicative biofuel targets of 2% by 2005 and 5.75% by 2010 (COM 2003). In 2005, the EC issued a Biomass Action Plan to increase the use of biomass for energy production, heat, power and transport. The objective of the plan was to double the use of bioenergy sources (i.e. wood, wastes and agricultural crops) in the EU’s energy mix by 2010. With regard to biofuels, the EC proposal is that biodiesel for transportation will account for 56% of biofuels consumption and that 70% of the biodiesel (or the raw material) will be imported. The plan expresses concern about the environmental impacts of the current expansion of palm oil and soy in producer countries, and points to the need for a certification system (COM 2005). At the end of 2008, the Renewable Energy Directive (RED) and Fuel Quality Directive (FQD) came into force; these Directives impose 20% targets for renewables across the EU by 2020. The RED introduced a binding target for 10% of the energy used in transport to be from renewables by 2020 on condition that they are sustainable (COM 2009), while the FQD could raise the percentage of biofuels to 15% of transport fuel (by energy) by 2020, depending on the final target and the extent to which other renewable fuels are used (RFA 2008)

1.2 Certification

The prospect of increased global trade in biomass and biofuels has raised several important issues, such as the sustainability of biofuels and their feedstocks, compliance with trading agreements and impacts on producer countries. A growing number of certification schemes are being developed to address these issues, for example, the EC, together with input from private and public stakeholders, is working on sustainability standards for biofuels, which aim to mitigate the potential deleterious impacts of increased production and trade in biofuels. This scheme is likely to be based on existing certification initiatives, such as the

Round Table on Responsible Soy (RTRS), the Better Sugarcane Initiative (BSI), the Roundtable on Sustainable Palm Oil (RSPO), the Forest Stewardship Council (FSC) and the Roundtable on Sustainable Biofuels (RSB). The proposed standards will be either voluntary or enforced by national laws (Schlegel and Kaphengst 2007; RSB 2008).

In this paper, we focus on the RTRS, an international multi-stakeholder initiative that 'brings together those concerned with the impacts of the soy economy' (RTRS 2009a). Founded in 2006, the RTRS was set up to promote the responsible production of soy, whilst reaching consensus among key stakeholders and players linked to the global soy industry (RTRS 2009a). One of the principal aims of the roundtable is to develop a global standard for the production of responsible soy and a verification mechanism to enforce these standards. However, the initiative has not been without its critics, not least in its failure to prohibit the use of genetically modified (GM) soy, which has led to condemnation by many Non-Governmental Organisations (NGOs) (Visseren-Hamakers and Glasbergen 2007). Furthermore, the meaning of 'responsible soy' is still to be defined by the initiative.

In June 2009, the RTRS published a field testing version of principles and criteria for responsible soy (see Table 1). This version will be available for field testing for 1 year to enable soy producers to test the implementation of the requirements. After this test period, a final revision will be made that will build on this practical experience to produce a first full version of the RTRS principles and criteria (RTRS 2009b).

This paper reviews the evidence related to the environmental and social impacts associated with the production of soy in one producer country, Argentina, and asks whether the RTRS principles and criteria will be able to address these impacts.

2 Argentina supplies a new market

Argentina is well placed to respond to the expanding international markets for biodiesel and soy is the crop on which both agribusiness and government are focusing as the principal feedstock for global biofuel markets. Soy is already the country's major export, principally to Asian markets (as beans, flour and oil) and to the EU (as cattle feed). The country is also one of the top three producers and exporters of vegetable oils and the largest exporter of soybean oil in the world (Franco 2007; Tomei and Upham 2009).

In Argentina, soybean is produced as an annual mono-crop (49%) or combined in a rotation with wheat (30.6%) or to a lesser extent maize and sunflower, all of which use no-till (NT) agriculture (Panichelli et al. 2008; Salado-Navarro and Sinclair 2009). Over the last 40 years Argentina has experienced a revolution in soy production; in the early 1970s, soy was cultivated on 26,000 ha, but by 2007/08, 16.4 million hectares (Mha) of soy were cultivated in Argentina (see Figs. 1 and 2), with production reaching 46.2 million tonnes (MAGyP 2010). Over this period, Argentina has developed an extremely economically efficient and export-focused agricultural sector. A lack of agricultural subsidies means that the sector is characterised by the rapid uptake and diffusion of new technologies and knowledge. Furthermore, the use of a technological package consisting of genetically modified (GM) soy, glyphosate and conservation or NT agriculture has led to yield increases and the consolidation of the dominant agro-export model. However, despite these technological advances, the sector is still vulnerable to external shocks: in 2008/09, despite an increase in the total area cultivated with soy (which reached 16.8 Mha), the country's worst drought for a century led to dramatically reduced yields and production fell to an 8 year low at 30.9 million tonnes. However, analysts expect Argentina's soy area to rise even higher during the 2009/10 season to reach a record 19–20 Mha (USDA 2009).

Table 1 Round Table on Responsible Soy principles and criteria for responsible soy

Principle	Criterion text
1. Legal compliance and good business practice	• There is awareness of, and compliance with, all applicable local and national laws. • Legal use rights to the land are clearly defined and demonstrable. • There is a commitment to continuous improvement with respect to the requirements of this standard.
2. Responsible labour conditions	• Child labour, forced labour, discrimination and harassment are not engaged in or supported. • Workers, directly and indirectly employed on the farm, and sharecroppers, are adequately informed and trained for their tasks and are aware of their rights and duties. • A safe and healthy workplace is provided for all workers. • There is freedom of association and the right to collective bargaining for all workers. • Remuneration at least equal to national legislation and sector agreements is received by all workers directly or indirectly employed on the farm.
3. Responsible community relations	• Channels are available for communication and dialogue with the local community on topics related to the activities of the soy farming operation and its impacts. In areas with traditional land users, conflicting land uses are avoided or resolved. • A mechanism for resolving complaints and grievances is implemented and available to local communities and traditional land users. • Fair opportunities for employment and provision of goods and services are given to the local population.
4. Environmental responsibility	• On and off site impacts (both positive and negative, both social and environmental) of large new infrastructure being built on the farm have been assessed and appropriate measures taken to minimise and mitigate any negative impacts. • Pollution is minimised and production waste is managed responsibly. • Efforts to reduce emissions of Greenhouse Gases (GHGs) are made. • Expansion for soy cultivation during field test period may not take place on land cleared of native habitat after May 2009. Exception: Producers who want or plan to clear native habitat after the cut-off date of May 2009 must produce scientific evidence from a comprehensive and professional third-party assessment of the area concerned that identifies the absence of: all primary forest; other High Conservation Value Areas (HCVAs); local peoples' lands.
5. Good agricultural practice	• The quality and supply of surface and ground water is maintained or improved. Natural vegetation areas around springs and along natural watercourses are maintained or re-established. • Soil quality is maintained or improved and erosion is avoided by good management practices.

Table 1 (continued)

Principle	Criterion text
	• Negative environmental and health impacts of phytosanitary products are reduced by implementation systematic, recognised Integrated Crop Management (ICM) techniques. • All application of agrochemicals is documented and all handling, storage, collection and disposal of chemical waste and empty containers, is monitored to ensure compliance with good practice. • Agrochemicals listed in the Stockholm and Rotterdam Conventions or banned by the Pesticide Action Network (PAN) Dirty Dozen are eliminated. • The use of biological control agents is documented, monitored and controlled in accordance with national laws and internationally accepted scientific protocols. • Systematic measures are planned and implemented to monitor, control and minimise the spread of invasive introduced species and new pests. • Appropriate measures are implemented to prevent the drift of agrochemicals to neighbouring areas. • Appropriate measures are implemented to allow for coexistence of different production systems. • Origin of seeds is controlled to improve production and prevent introduction of new diseases.

Source: RTRS 2009b

For those involved in Argentina's soy industry, growing international demand for biodiesel offers new opportunities to benefit from the soy revolution of the past 15 years (Mathews and Goldsztein 2009). To meet this demand, Argentina's biodiesel industry is developing rapidly; increasing from 155,000 tonnes in 2006 to 1.4 million tonnes in 2008, with more than 20 biodiesel projects launched in 2007 alone (CAER 2008). Biodiesel production capacity was estimated to increase to 3.9 million tonnes by 2011 (ibid), but these projections are likely to be affected by the ongoing economic uncertainties (Tomei and Upham 2009). Supplying the planned expansion is also likely to require imports of soybeans from Paraguay, Brazil and Bolivia (USDA 2009).

The expansion of the soy-based biodiesel industry is expected to bring economic benefits to the country, largely in the form of increased revenue from export taxes on soy-based commodities, including biodiesel. However, while the economic benefits associated with increased global demand for biofuels will fall to those who dominate the soybean value chain, particularly large agribusiness firms and multinationals, such as Dreyfus and Bunge, the negative environmental and social effects of the unplanned expansion of intensively produced soybean have to date been overlooked and under-researched.

3 The institutional context

Institutional and societal contexts are crucial to understanding and resolving environmental issues, but in Argentina the financial constraints of the state have negatively affected

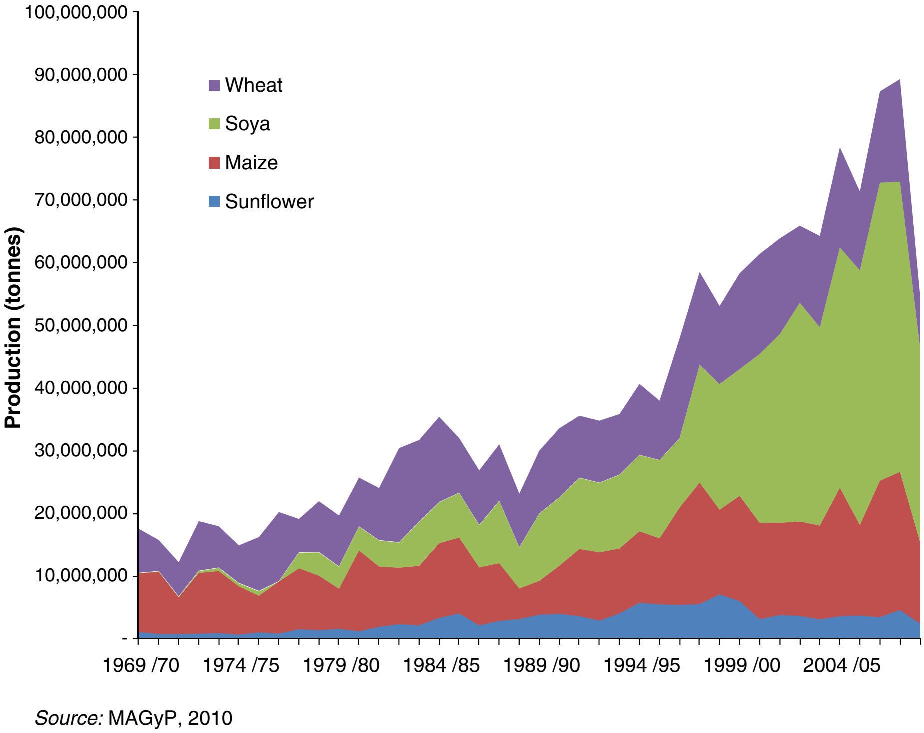

Fig. 1 Evolution of grain production in Argentina, 1969/70 to 2008/09. *Source:* MAGyP 2010

environmental policy making. Furthermore, the transition from a dictatorship to a democracy has been marked by corruption and a lack of accountability (O'Donnell 1999).

In the 1990s, the Argentinean state, following World Bank recommendations, reformed administrative institutions. As a result, the Ministry of Agriculture was converted into a secretariat dependent on the Ministry of the Economy (Gobierno Argentino 1996). Between 1970 and 2000, Argentina acquired an enormous debt, difficulties with the payment of which led to the 2001 economic crisis (Cafiero and Llorens 2003). Soybean production has helped Argentina to overcome the crisis as taxation of soybean exports is high and revenues go to the Treasury to help service the national debt (Semino 2004). The fact that agricultural affairs are conducted by the Treasury greatly reduces public awareness of the environmental problems generated by soybean cultivation. In addition, partnerships between statutory bodies, professional associations and the private sector further decrease public participation in analyses of the environmental impact of agriculture (Ekboir and Parellada 2002). As the majority of the Argentinean populace live in urban areas they do not see and are often not interested in rural issues, which is compounded further by policies favouring urbanisation.

Since the 1990s, policy has favoured larger producers who are able to capitalise upon the economies of scale inherent in industrialised agricultural systems. Argentina is also increasingly characterised by tenant farmers, who are again able to capitalise on economies of scale; in 2008, 55% of grains were produced by farmers that did not own the land they cultivated (Van Dam et al. 2008). These tenant farmers often have little interest in the long-term viability of the land and prioritise short-term economic gains. A weak public sector and inadequate agricultural policies have contributed to the increasing concentration of

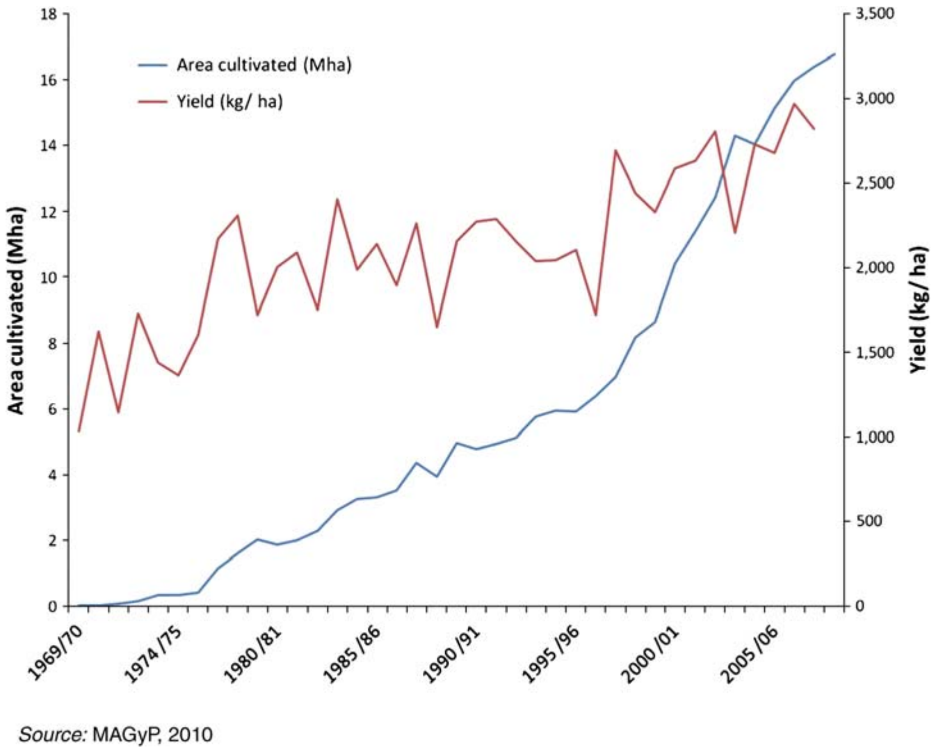

Fig. 2 Argentinean soy production hectares cultivated and yield per hectare, 1969/70 to 2008/09. *Source:* MAGyP 2010

agricultural production and management (Manuel-Navarette et al. 2009). Furthermore, the weakening of government institutions charged with providing agricultural services, such as extension services and diffusion of technologies, has increased the participation of private actors in the agricultural sector. Manuel-Navarette et al. (2009) argue that this has important implications for sustainability as these actors are not obligated to defend common interests (p. 628).

Weak agricultural and environmental policies are further eroded in the provinces, where inadequate funding and a focus on short-term needs, means that local priorities are often overlooked in favour of private interests. In areas where the environment is afforded a low priority, environmental policies can be extremely difficult to enforce. In many provinces environmental regulations appear to be comprehensive but in reality are often not complied with. An example of this occurred within the province of Santa Fe, which is located in the heart of the soy producing region, has comprehensive regulations that cover the use of agrochemicals (Provincia de Santa Fe 1977); however, these regulations are often ignored. In 2007, the Provincial Ombudsman advised the provincial government to establish an agronomic border between urban areas and cultivated fields, as stipulated by the law (Defensoria Provincia de Santa Fe 2007). However, despite this resolution, the fumigations continued until 2009 when residents affected by the spraying of pesticide obtained a court injunction on the grounds that the practice violated their constitutional right to a healthy environment (Juzgado CCL, nro. 11, San Jorge 2009).

4 Environmental impacts of soy production

Two RTRS principles cover the potential deleterious impacts of soy production: Environmental Responsibility (Principle 4) and Good Agricultural Practice (Principle 5) (RTRS 2009b). In this section we discuss some of the key environmental impacts of Argentinean soy production, all of which are potentially covered by RTRS criteria. Our premise here is not to provide a comprehensive review of the evidence, but rather to highlight some of the key impacts associated with the intensive cultivation of soy in Argentina and the urgent need for further research in many, if not all, of these areas.

4.1 Land use change and deforestation

Over the past few decades, Argentina has experienced rapid land use change, one of the principal drivers of which has been the expansion of intensively cultivated annual crops and cattle raising (Zak et al. 2008). The adoption of an intensive agro-export model has displaced the agricultural frontier towards areas of native habitat, such as the Chaco subtropical forests, where the clearance of forests, woodland and scrub is carried out by machines, fire or by aerial applications of herbicides (Semino 2008). In contrast to other countries in Latin America, where agricultural colonisers are typically poorer farmers, in Argentina the expansion of the agricultural frontier is driven by entrepreneurs with substantial financial capital (Boix and Zinck 2008) (Fig. 3).

For Grau et al. (2005) attention and research into the extent of the deforestation caused by soybean expansion in Argentina have been minor compared to the attention given to the Brazilian rainforest. In their research, the authors find evidence of a positive relationship between soybean prices and deforestation, which they suggest shows that only by creating conditions unfavourable for soybean production in the longer term is deforestation likely to be reduced in any significant way (Grau et al. 2005). Habitat loss due to soy conversion is ongoing; in 2009 the Province of Salta approved the conversion to soy cultivation of 1,670 hectares of the Yungas, the largest UNESCO biosphere reserve in Argentina. This should perhaps not be surprising when Gustavo Lopez Ascencio, a former environment secretary

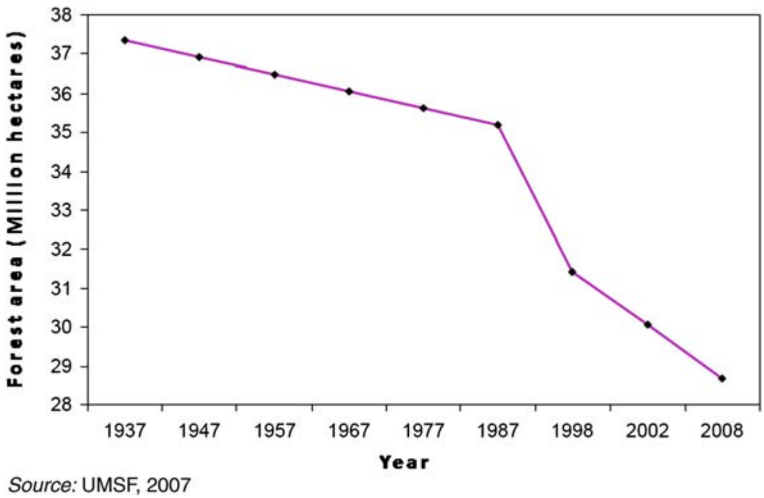

Fig. 3 Native forest clearance in Argentina, 1930 to 2008 (million hectares). *Source*: UMSF 2007

for the province, was reported to have said ‘deforestation is a stage in the productive process and the long-term positive impact is more important than immediate negative impacts’ (Clarin 2007). This pattern is mirrored elsewhere, for example in the Chaco region, there are plans to incorporate in the medium term about 3,000,000 hectares of new lands for the production of biofuel feedstocks, including soybean (Pengue and Morello 2007).

Deforestation leads to the direct loss of carbon both above and below ground, and is one of the major contributors to climate change, producing around 20% of global carbon emissions and destroying long-term sinks (Gullison et al. 2007). When deforestation is followed by agriculture, further release of soil carbon occurs due to disturbance by tillage. Publication of research by Searchinger et al. 2008 brought the issue of indirect impacts of biofuels to the fore. Searchinger et al. argued that uncontrolled expansion of biofuels could drive changes in land use that may increase overall greenhouse gas (GHG) emissions, as well as increase the price of food. Although this research have been criticised by some (e.g. Sylvester-Bradley 2008), further research will be required to address the many uncertainties surrounding the indirect impacts of biofuels.

Since 2007 national legislation, *La Ley de Bosques* (Law of the Forests, Law No. 2386), has prohibited the clearance of native forests, yet this legislation has proven difficult to enforce. Explicit requirements within the law for the full participation of all affected stakeholders, including indigenous communities, have not alleviated the problem. In 2008, more than a year after the law came into force, it was estimated that around 137,000 hectares of native forest in the north of Argentina had been cleared (UMSF 2008). In January 2009, rural organisations from six Argentinean provinces reported that deforestation had continued unabated (Página12 2009a) and, at the time of writing, the situation has yet to improve (pers. comm).

4.2 Emissions from soy cultivation

Based on data from the Second Communication on Climate Change (Gobierno Argentino 2007), Petrillo (2008) estimated emissions of N_2O and CO_2 from fuel and fertiliser consumption during the 2003/04 agricultural season. Considering only the principal crops (wheat, maize, sunflower (*Helianthus annuus*) and soybean), the author estimated indirect and direct emissions of N_2O to amount to 42.61 Gg. The principal sources of N_2O from these crops were nitrogen fixation by soy (45.2%), crop residues (37.6%) and fertiliser use (17.2%). The consumption of diesel during the 2003/04 season reached 735 million litres (Ml), giving an estimated 1948.9 Gg CO_2 from Pampean agriculture.

In terms of the GHG balance of soy-based biodiesel, the evidence is inconclusive. Some US studies have shown that the energy balance for soy-based biodiesel is negative, requiring 27% more fossil energy than conventional diesel (Pimentel and Patzek 2005), while other studies claim the opposite- that soybean biodiesel provides around 93% more energy than is required in its production (Hill et al. 2006). Using the UK Department for Transport default values for the carbon intensity of biodiesel types, Upham et al. (2009) demonstrated that, depending on the reference land use, Argentinean soy biodiesel gives a 44%, −1134%, and −109% saving for converted cropland, forest and grassland respectively. Furthermore, emissions of N_2O have a strong influence on the net GHG balance of soybean-based biodiesel. For example, Smeets et al. (2009) found that, depending on how N_2O emissions were estimated, the GHG balance of soybean biodiesel could vary from +44% to −111% when compared to fossil fuel alternatives. However, research rarely takes into account N_2O emissions (Mosier 1998).

Another area of contention with regards to the LCA performance of many biofuels, including soy-based biodiesel, is the issue of co-product allocation. Allocating energy and GHG credits to co-products makes the untestable assumption that substitution takes place, ignoring the net increase in production and effects external to the LCA system boundary (Saynor et al. 2003). For soya this issue is critical. Growing global meat consumption is increasing demand for animal feed and soy is used as a high protein input in livestock feed in many countries. The combination of increasing demand for animal feed and for soy oil for biodiesel production will interact to drive expansion of the soy industry further still.

A country-specific approach to assessing GHG balance is vital when estimating the sustainability impacts of bioenergy systems, yet there have been few studies to date that are specific to Argentina (cf. Dalgaard et al. 2008; Panichelli et al. 2008). One study of emissions from Argentinean soy-based biodiesel was carried out by Panichelli et al. (2008). This research used an economic allocation approach to analyse the environmental performance of soy-based biodiesel produced in Argentina for export. The study found that the 'agricultural phase' of soy-based biodiesel accounted for more than 80% of global warming potential, primarily due to land use change. The authors concluded that "the global warming potential of biodiesel production in Argentina... is higher than the fossil reference and consequently is not a good choice to mitigate global warming" (p.150). The high global warming potential value was largely attributed to land use change i.e. deforestation and habitat loss.

Van Dam et al. (2009) also investigated the environmental impacts of large-scale bioenergy production from soybeans. However, this analysis was based in the province of La Pampa, which is not at the heart of Argentina's soy producing region (production is concentrated in the provinces of Buenos Aires, Santa Fe, Cordoba and Entre Rios). The authors found that GHG emission reductions ranged from a 16 to 94% reduction, depending on the lifetime period (20 to 100 years) and original land use (abandoned cropland, non-degraded and degraded grassland). However, the authors caution that the accuracy of the input data is highly variable and call for improvements in field data collection and assessment methodologies (p.1706). Further research on the emissions associated with soybean production, that takes into account local conditions, will be essential in order to fully evaluate the GHG benefits of Argentinean soy-based biodiesel.

4.3 No-till agriculture

No-till, or conservation, agriculture involves the growing of crops without traditional tillage to minimise soil disturbance and conserve water and soil. Emphasis is placed on the management of crop residues and special planting equipment is used to sow the soil directly (Lal et al. 2007). In addition to erosion control, environmental benefits associated with no-till include: energy savings, increased agricultural biodiversity and enhanced soil biological activity (ibid).

The technology has been adopted most enthusiastically in South America, where no-till is used on a continuous basis; Argentina alone comprises some 20% of the world's no-till acreage (Econexus 2009), with an estimated 19–20 Mha under no-till in 2008 (AAPRESID 2008). No-till was adopted by Argentinean producers in the 1990s due to increasing concerns about soil degradation, the availability of GM seeds, advances in weed control and reduced cost of agrochemicals (Casas 2003; Joensen et al. 2005). Despite the purported environmental benefits associated with no-till, Alvarez and Steinbach (2009) ascribe the high rate of adoption by Argentine producers to 'economic reasons' (p.2). Research into no-till agricultural systems in Argentina has demonstrated some improvements in the conservation of organic matter, enhanced soil water content and water use efficiency (Marraro 2004; Alvarez and Steinbach 2009). However, in other areas the results are less conclusive; for example, Alvarez and Steinbach (2009) in a review of field experiments that compared conventional tillage and no-till systems found that other benefits were less conclusive, for example investigations into yields and soil productivity were dependent on the experimental plots and assumptions about soil compaction.

Concerns about climate change have led to increased interest in soil carbon storage and, therefore, in agricultural systems that reduce carbon loss, such as no-till. According to the Intergovernmental Panel on Climate Change (IPCC 2007), conversion from conventional tillage to no-till leads to a 10% increase in the estimated sequestration of carbon in the soil. However, this is not always the case as several studies have shown (e.g. Baker et al. 2007; Yang et al. 2008; Franzluebbers and Studemann 2009). For example, Baker et al. (2007), through a review of studies that examined carbon sequestration in no-till systems, suggest that sampling protocol may have biased the results. In the majority of the studies they reviewed, soils had been sampled to a depth of 30 cm or less, while the few studies that sampled at deeper levels found that no-till showed no consistent build up of organic carbon in the soil, leading the authors to conclude that the evidence for increased carbon sequestration in no-till systems was not compelling. Emissions of nitrous oxide (N_2O) may also be higher under no-till soils (IPCC 2007; Lal et al. 2007), which must be considered in order to develop a more realistic picture of GHG emissions from agriculture (Mosier 1998; Marraro 2004). For example, in 2006 an Argentinean study demonstrated that the average sequestration of carbon was lower than the IPCC estimate and suggested that higher N_2O emissions in no-till systems in the Humid Pampas might offset the sequestration of carbon within a few decades (Steinbach and Alvarez 2006). Furthermore, there has been little research into what happens during soy defoliation: the Second National Communication on GHG emissions from agricultural activities (Taboada 2004) acknowledges "it is assumed that agricultural residues are buried, however, conclusive information does not exist about the possible emissions from the 14 Mha under no-tillage" (p.33).

4.4 Pesticide use

Genetically modified Roundup Ready (RR) soy was first cultivated commercially in Argentina during the 1996/97 season. RR soy has been genetically engineered for resistance to glyphosate, the active ingredient in the herbicide Roundup (Duke and Powles 2008). Glyphosate is a wide-spectrum herbicide that is used post-emergence; it is classified as 'relatively harmless' due to a lack of residual activity and rapid decomposition to organic components by soil micro-organisms (Qaim and Traxler 2005).

Prior to the introduction of GM soy, weeds led to lower yields and control was expensive and met with only limited success (Tuesca et al. 2007). Today, glyphosate is the principal herbicide used in Argentina and accounts for more than 70% of the agrochemicals used in 2007 (ibid). Promoters of the technology argue that a single application of herbicide is sufficient, but other studies have shown that the adoption of GM soy increases both the volume and number of applications of glyphosate (SAyDS 2008). The average concentration of glyphosate applied by producers has also increased over this period, from 48.9% in 1999 to 54.4% in 2008 (CASAFE 2000, 2008).

In 2008, herbicides had a 68% share of pesticide sales, followed by insecticides (13%), fungicides (11%) and seed treatment fungicides (6%) (CASAFE 2008); see Fig. 4.

According to the Argentine government, annual sales of glyphosate increased from 13.9 million litres in 1996, when RR soy was first introduced, to more than 200 million litres in

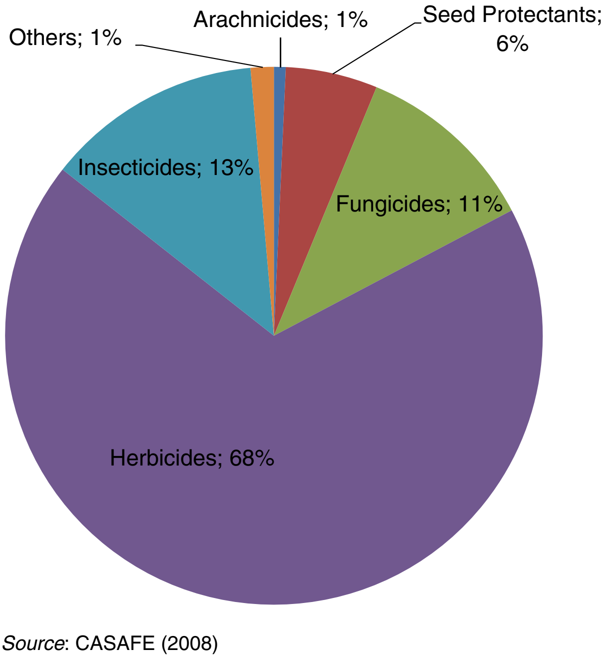

Fig. 4 Consumption of pesticides in Argentina, 2008. *Source*: CASAFE (2008)

2009 (Grain 2009). The Argentine market for other herbicides has also increased: in 2000, 28.1 million kg (or l) of herbicides was sold, increasing to 38.8 million kg (or l) in 2007 (CASAFE 2008). The market for insecticides more than doubled between 2000 and 2008; from 11 million kg to 25 million kg respectively (CASAFE 2000, 2008). These data are presented in Fig. 5.

The fall in the use of pesticide use during the 2008/09 agricultural season (shown in Fig. 5) has been attributed to several factors, including the political and financial situation of farmers in that year, but principally due to the increase in the price of many agricultural

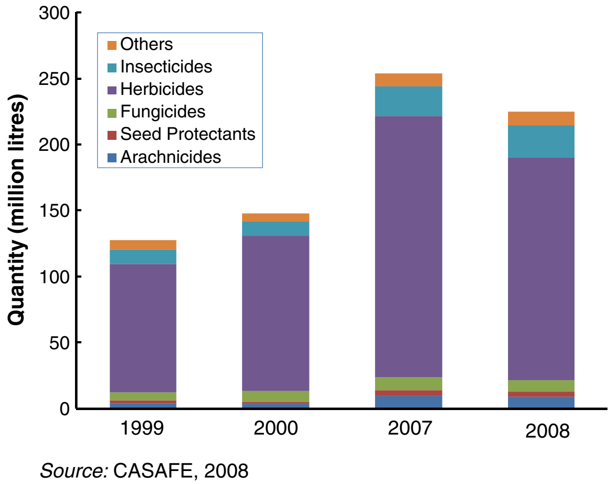

Fig. 5 Consumption of pesticides in Argentina, 1999 to 2008. *Source:* CASAFE 2008

inputs (e.g. ASA 2008; Garcia 2009). For example, between 2006 and 2008 the price of fungicides increased by more than 120%, while the price of herbicides increased by 97% (CASAFE 2008). The drought in the 2008/09 season also reduced yields, lessening the need for pesticides and particularly for fungicides.

In Argentina, the modification of agricultural systems, through technologies such as NT and the use of GM soy, has led to changes in the composition of weed communities. These changes are not only observed in the quantity of weeds, but also in the increased incidence of some weed species such as Johnson grass (*Sorghum halepense*) (Faccini 2004; Tuesca et al. 2007; Faccini et al. 2008). As a result, recent years have witnessed a substantial increase in the number of farmers, technicians and students seeking advice about how to deal with the increased incidence of weeds (INTA 2003; Puricelli et al. 2007; Tuesca et al. 2007). A 2008 communication by the Argentine Government also cautioned about increasing resistance to glyphosate, citing 216 known cases of resistance to one or more family of chemical herbicide (SAyDS 2008).

4.5 Soil quality

The use of fertilisers has traditionally been low in Argentina due to the fertility of the soils, but since the 1990s the use of fertilisers has been increasing steadily (see Fig. 6).

In 2007, fertiliser use reached a peak of 3.7 million tonnes; of this, nitrogenised fertilisers accounted for 1.7 million tonnes and phosphate fertilisers for 1.6 million tonnes (CASAFE 2008). As with pesticides, a marked increase in the prices of inputs led to a fall in the use of fertilisers during 2008.

In the Argentinean Pampas, the intensive cultivation of soybean has led to by steep declines in soil nitrogen (N), phosphorous (P), potassium (K) and sulphur (S) (INTA 2007). Of the principal crops produced in Argentina, soybeans have the highest rates of nutrient extraction and, despite the capacity of soybeans to fix nitrogen biologically, nitrogen deficiencies are especially high (Cruzate and Casas 2009). Nutrient balances for the 2008/09 growing season estimated that only 50%, 56%, 3% and 43% of the N, P, K and S respectively removed during grain cultivation were replaced through the application of fertilisers (Garcia 2009). Declining soil fertility has raised concerns about the long-term physical, ecological and economic sustainability of the region. According to Pengue (2009) the continuous production of soy is extracting around 1 million tonnes of nitrogen and 300,000 tonnes of phosphorous annually. He estimates the cost of replacing lost nutrients at US$2,000 million, equivalent to around 20% of export revenue from soy. While maintaining soil fertility is critical to the long-term sustainability of agricultural production,

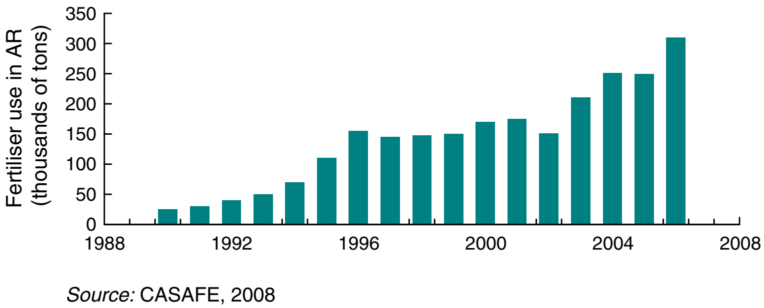

Fig. 6 Fertiliser use in Argentina, 1988 to 2006. *Source:* CASAFE 2008

it is unlikely to be willing to pay for additional agricultural inputs as long as they can maintain high yields. Under these circumstances, and due to growing global demand for oilseeds, Forjan (2006) argue that soil fertility losses are likely to continue for the foreseeable.

4.6 Water resources

In the Argentinean Pampas, the use of irrigation is not common practice. Although soy has high water requirements during the mid to late growing season, water needs are generally in line with the region's precipitation pattern (Van Dam et al. 2009). Water shortages can however impact crop yields; the 2008/09 drought, for example, affected crop production and led to the lowest soy yields for 8 years (MAGyP 2010). Continuous agricultural production has left the soil with a reduced capacity to absorb water as it drains from the surface, contributing to flooding in some areas (Marraro 2004; Monti 2008) while reducing the capacity of plantations to resist periods of drought in others (Sasal et al. 2008).

Water contamination from the use of agrochemicals is thought to be high, but to date there has been only limited research in this area (Van Dam et al. 2009). However, only a limited amount of the agrochemical that is applied reaches the intended recipient, whilst the rest leaches elsewhere, which will have negative impacts on both surface and groundwater quality. Intensive cultivation has also led to declining soil organic matter which in turn has reduced the natural capacity of soils to attenuate contaminants, particularly heavy metals and micronutrients, which may leach into groundwater sources (INTA 2007). Furthermore, research has also raised concerns that current agricultural practices, which rely heavily upon continuous additions of glyphosate, may alter the structure and function of many natural aquatic environments (Perez et al. 2007). As water quality is highly spatially variable, more research is needed to determine the impacts of agricultural production on local water quality

4.7 Conventional breeding: an alternative to GM?

Panichelli et al. (2008) acknowledged some of the negative impacts of soybean cultivation and to address these impacts proposed an increase of 10% in the soybean yield, whilst keeping the inputs constant. As already noted, 98% of soy in Argentina is GM, but Steinbrecher and Lorch (2008) state that "none of the existing GM crops in commercial cultivation are engineered specifically for yield increases" and that instead it is conventional breeding that has led to higher yielding varieties. Given that current varieties are probably close to their yield ceiling, a sharper yield increase could be achieved by changes in agricultural practices. For example, agro-ecological practices, such as using green manures, contour grass-strips and in-row tillage, have been shown to lead to yield productivity increases of 50% as compared to conventional intensive monoculture systems. If practices remain the same, including the use of GM herbicide tolerant crops, the only possible avenue for yield improvement is to breed higher yielding varieties and then to genetically engineer them for herbicide tolerance or to cross them into current herbicide tolerant lines.

The yield lag observed for many GM crops may partly be the result of the time lag between the development of a new conventional variety and the development of a GM version of that variety. However, it has been shown that some varieties of GM soybean actually had a yield decrease compared to their non-GM isolines (Benbrook 2001). Another study showed that RR soy would only yield as well as conventional varieties if manganese were added to the soil (Gordon 2007). According to data from the American Soybean Association, US soy yields increased on average (in kg/ha) by 1.16% per year between

1986 and 2007. Before the introduction of GM in 1997, the annual yield increase was 1.53%, but since then it has dropped to 0.64% (Steinbrecher and Lorch 2008).

5 Social impacts of soy production

Three principles within the field-testing version of the RTRS Principles and Criteria (RTRS 2009b) cover the socio-economic impacts of soy production: Principle 1 (Legal Compliance and Good Business Practice), Principle 2 (Responsible Labour Conditions) and Principle 3 (Responsible Community Relations). In this section, we examine the socio-economic impacts of soy production in Argentina, focusing on the impacts on rural communities and rural livelihoods.

5.1 Human health impacts

The Argentinean soy revolution of the past 20 years has been accompanied by the increased use of agrochemicals, applied either by aerial and terrestrial spraying, which has had negative health impacts on rural communities. Epidemiological studies of long-term exposure to pesticides are lacking in Argentina; in 2004, a World Bank/ FAO study reviewed three national registers and found that the lack of information was due to an absence of human resources and/ or training of health professionals on keeping records, as well as a lack of transparency. The report concluded that there was no epidemiological information or registers about the negative effects on human health of pesticides in Argentina. Furthermore, there has been no review of the national legislation related to pesticides and toxicity categories since 1996 (WB/FAO 2004, FODEPAL 2005). However, vast anecdotal evidence from rural communities has pointed to a high incidence of cancers, skin and respiratory diseases in people living near crop-spraying areas (GRR 2009), while scientific studies have provided evidence of increased birth malformations in soy producing regions (Benachour et al. 2007; Benítez-Leite et al. 2009). The most frequent type of toxic exposure in rural communities in Argentina can result in chronic illnesses from long or constant exposure to low quantities of agrochemicals. This type of contamination is difficult to diagnose, which makes it harder for communities to provide irrefutable evidence to support any complaints they make (GRR 2009). Andrés Carrasco, a senior scientist at the research institute CONICET (*Consejo Nacional de Investigaciones Científicas y Técnicas*) currently researching the impacts of glyphosate, compared the situation in Argentina to a “massive eco-toxicological experiment” (Página12 2009b). An increasing body of evidence demonstrates that despite laws in some provinces that ban the spraying of pesticides within 3,000 m of communities (e.g. Ley 11273 de la Provincia de Santa Fe), aerial fumigations continue unabated with deleterious effects on the health of communities (GRR 2009; Página12 2009a).

5.2 Rural livelihoods

Over the past 20 years, the Argentine government has undertaken three National Agricultural Censuses (INDEC 1988, 2002, 2008). During the last census the Government experienced data collection difficulties, with many producers refusing to collaborate (CDN 2009). As of November 2009, the Government was obliging producers to provide a certificate of compliance with the census or face financial penalties (ibid). However, the data set remains incomplete for most regions and thus we draw here only on the first two agricultural surveys. The last complete census was carried out in 2002, when total soya cultivation accounted for less than 11 million hectares, and indicated a massive exodus from rural to urban areas (see Table 2) with the number of rural workers declining from more than 1 million in 1988 to 775,000 in 2002.

Between 1988 and 2002, an estimated 60,000 small and medium farmers left the agricultural sector (Giarracca and Teubal 2002) and, although complete figures have yet to be published, early reports indicate that in the 6 years since the last agricultural census, the number of farms has declined by almost 57,000 (Momento24 2009). The intensification, mechanisation and specialisation of agriculture has led to a reduction in the labour force; whereas small farms may create 1 job per 8 hectares, mechanised plantations may employ as few as 1 person per 200 hectares (Dros 2004; Van Dam et al. 2008). The specialisation of agriculture has also increased highly-qualified human capital within Argentina, again facilitating production on a larger scale. Migration from rural to urban areas is likely to occur when farmers, agricultural workers and their families, find they can no longer make a living from the land and there is anecdotal evidence of population increases in city slums due to land use change (Página12 2009c). There have also been reports of smaller farmers being driven off their land, often under threats and violence (Página12 2007). The rural exodus has led to the weakening of rural communities, with the subsequent loss of traditional livelihoods, knowledge and production schemes (Manuel-Navarette et al. 2009).

Another recent phenomenon affecting rural livelihoods is the increase in land rented to well-capitalised enterprises. These companies are managed by investment groups, or *pooles de siembra*, many of which have links with the agrochemical industry. The *pooles de siembra* are attracting investment as land price increases and people begin to invest and speculate more in land. According to the *Federación Agraria Argentina*, the local production chain, and thus food security, is greatly affected by these investment groups, whose focus is on the production of commodities rather than food for local populations (Federación Agraria 2007). More research is needed on the impact of the *pooles de siembra* on the agricultural sector and rural social structures in particular.

5.3 Other social impacts

In Argentina, there are concerns that the current focus on the production of agricultural commodities is threatening food sovereignty, with reports of declining beef and dairy production and of an imminent need to import wheat (cf. Mercopress 2009; Wasilevsky 2009). Although the agricultural sector produces more food than is required by the

Table 2 Argentinean agricultural census, 1988 and 2002

Agricultural census	Year	
	1988	2002
Total rural workers	1,032,121	775,296
Quantity of productive farms	421,221	317,816
Total surface of productive farms (hectares)	177,437,398	171,331,163
Average surface productive farms (hectares)	421	538
Number of cattle	47,075,156	46,964,059
Surface cultivated with oil seeds (hectares)	4,328,847	10,835,300

Source: INDEC 2002

Argentine population (Lamers et al. 2008), if soy cultivation displaces vital foodstuffs then its expansion poses a genuine threat to food security. More research is needed on the potential impacts on food security in Argentina of increased global demand for biofuels.

Land use change, driven by agricultural expansion, has led to the degradation of critical ecosystem services, which inevitably has negative impacts on rural communities. In February 2009, Tartagal, a community in Salta, was hit by a landslide, which killed two people and left thousands homeless. An official report into the disaster concluded that human activities, including forest loss (to both the agricultural and timber industries), extractive industries and civil infrastructure projects, had led to the disaster. The report called for urgent work to enhance the region's sustainability, including reforestation, a halt to oil exploration and strict controls over deforestation. According to reports, the Provincial Government however dismissed these findings, insisting that the disaster had been caused by natural factors (Página12 2010). In addition to the loss of ecosystem services, there are unofficial reports of indigenous communities, such as the Wichi, the last hunter-gatherer culture in Argentina, being forced to leave their land and livelihoods, threatened by the advance of agriculture (Página12 2008). Deforestation has also led to the increased incidence of some diseases including leishmaniasis, hanta virus and dengue fever mainly related to deforestation in regions where land is being converted to the production of soy (Salomon et al. 2006; Seijo 2008).

6 Can the RTRS promote 'responsible' soy production in Argentina?

Growing concern about the impacts of biofuel crop cultivation has led to calls for global certification of biofuels in order to ensure that their production is sustainable. In the UK, for example, one of the few countries to have reporting requirements, suppliers are not required to report on biofuel origins, carbon savings or sustainability. In July 2009, the UK Renewable Fuels Agency reported that only 24% of biofuel supplied in the first year of supply to UK forecourts had met the Government's target for sustainability, as compared to the 30% target for 2008/09 (RFA 2009a). Soy-based biodiesel represented 35% of the total biofuel supplied to UK forecourts, much of this imported from the US (RFA 2009b), although much of this is thought to have come from Argentina and then been re-exported.

Without sufficient evidence of the sustainable cultivation of biofuel feedstocks, the promotion of biofuels by industrialised countries cannot confer genuine carbon savings, and therefore must be considered premature. In response to the Gallagher Review (RFA 2008), which highlighted the lack of evidence regarding the indirect impacts of biofuel production, the UK Transport Minister announced in January 2009 revisions to the UK target for biofuels used in road transport fuels. The rate of increase of the Renewable Transport Fuel Obligation (RTFO) has been reduced to reach 5% in 2013/14 rather than in 2010/11. However, the recent publication of the UK Low Carbon Transition Plan increases this target once more to 10% by 2020 (HM Government 2009); we argue that the evidence presented in this paper shows that this may be too much, too fast.

The institutional challenges to a sustainable EU biofuel supply are also being underestimated. Certification schemes presume well-functioning institutions for environmental protection and monitoring, which often do not exist. Within Argentina, the enforcement of environmental legislation has proven to be difficult, as efforts to enforce the *Ley de Bosques* demonstrate (this paper). In producer countries, like Argentina, that prioritise economic development over sustainability, the absence of strong institutions to enforce environmental legislation should come as no surprise. The RTRS, or indeed any other certification scheme, proposes a chain of custody approach to control the supply chain and ensure the enforcement of environmental legislation. However, the OECD, in a study dedicated to the sustainable development of biofuels, warned that "enforcement and chain-of-custody control could prove to be an enormous challenge, as recent experiences with the certification of wood products has shown... Though theoretically possible reliance on certification schemes to ensure the sustainable production of biofuels is not a realistic safeguard" (Doornbosch and Steenblik 2007).

The standards proposed (see Table 1) aim to reduce the use of agrochemicals on GM soy and the subsequent impacts on human and animal health and the environment. However, due to the method and intensity with which GM soybean monocultures are cultivated in Argentina, there is an increasing need to use more pesticides. Furthermore, the emergence of further resistance to glyphosate would lead to a dramatic increase in the use of pesticides, reducing producers' profit margins and yields and worsening the environmental and social impacts associated with soy production. It is difficult to see how pesticide reduction can be achieved by either voluntary or mandatory sustainability standards, given the need for industry and producers to increase yields to the detriment of all else. Furthermore, the cultivation of macro impacts such as GHG calculations, population displacement and soil demineralisation, cannot be dealt with by the RTRS scheme alone.

Within Argentina, the direct and indirect environmental and social impacts associated with the production of GM soybean in Argentina have been overlooked and are under-researched. Current studies that examine the life cycle emissions associated with the production of soy could be considered flawed, all too often based on baseline data little suited to the vast range of Argentine geographies, with their different soil types, vegetation and water resources. The absence of research on the emissions of nitrous oxide from agriculture in Argentina is also alarming, while the issue of co-product allocation is likely to remain controversial and unresolved for the foreseeable. Research on the emissions associated with biofuels is vital to ensure that the production of biofuels is limited to cases where it confers genuine GHG savings.

The direct and indirect impacts associated with land use change are also a cause for concern and broad certification schemes are unlikely to be able to address them. Direct impacts include the loss of ecosystem functions, which are important both at a local and global level particularly as a means to mitigate climate change. Where native habitats are converted to agriculture, researchers have raised concerns about the suitability of the soil for the intense production of soybean as such soils are often fragile and prone to erosion. Links between the price of soy and rate of forest destruction in Argentina also highlight the dangers of further increasing international demand for soybeans through the development of global biofuel markets (Grau et al. 2005; Pengue 2009). Furthermore, the use of agrochemicals is, as we have shown, associated with negative effects on ecosystems and human health.

With regard to the social consequences of soybean production, we conclude that the RTRS cannot provide the necessary guarantees to those farmers who opt for more sustainable production systems that they will be economically protected by the state. Certification schemes alone will not be enough to create the appropriate public policies that will protect the health and food security of citizens or to provide the cultural and economic incentives to encourage citizens to remain in rural areas dominated by soybean production. Nor can certification schemes be allowed to substitute for sound long-term policy development. In spite of the short-term economic gains conferred on a minority of stakeholders, the losses will be felt by the majority in both the short and longer term.

A major impediment in writing this paper more specific has been the absence of quantitative empirical data on the effects of agrochemicals on the environment and human health, and the impacts of agricultural intensification on current population shifts. Furthermore, there is a lack of research relating to the impacts of a shift to soy production on food production in Argentina. Yet, such research is vital if certification schemes are to guarantee that biofuels production is restricted to situations where a genuine carbon saving can be demonstrated. A meaningful contribution to local livelihoods should also be a prerequisite for such schemes. Going down this path without doing the research could lead to irreparable damage to fragile ecosystems and the communities that depend on them.

A discussion of the institutional and economic conditions that underlie the present expansion of soy in Argentina is outside the scope of this paper and nor was there space to review certification standards other than those of RTRS. However, we note that existing environmental legislation is widely ignored within Argentina and there is no obvious reason why this situation should change in the foreseeable future.

7 Conclusions

This paper has highlighted the negative environmental and social impacts of the production of one biodiesel feedstock, soybean, on one producer country, Argentina. We have shown that in practice the political, social and economic conditions in producer countries can present significant obstacles to 'responsible' production. Furthermore, experience suggests that certification schemes, however well-meant, are unlikely to be able to address these issues. While the political, environmental and social conditions will vary according to feedstock and producer country, it is clear that there is much that is not yet understood about the impacts associated with the production of agricultural feedstocks and that further research, specific to local contexts, is urgently required. For Argentina, the development of LCAs that are specific to the production of feedstocks in different regions is a research priority. LCA should be carried out using data obtained *in situ* and not through computer modelling using standard data. The inclusion of geo-physical variables, inputs such as fertilisers and herbicides and the direct and indirect impacts related to land use change, will be vital to ensure that such studies adequately reflect the system being modelled. Finally, when answering the question of whether certification schemes are able to address the negative impacts of soy cultivation, we conclude that, at present, such schemes are unlikely to address the detrimental impacts of the additional demand generated by biofuels.

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