Agroforest Syst (2015) 89:1107–1118
DOI 10.1007/s10457-015-9839-1

Integrated beef and wood production in Uruguay: potential and limitations

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Received: 6 January 2015 / Accepted: 10 August 2015 / Published online: 20 August 2015

Abstract Silvopastoral systems (SPSs) in Uruguay have been developed in the context of a recently formed plantation forestry sector. Beef cattle farmers have long been adopting forestry mostly as woodlots or SPSs. In spite of the potential complementary relationship between forestry and cattle husbandry, research in temperate regions is scarce. The objectives of this study were to identify constraints for the inclusion of forestry in cattle farms and to assess expansion potential for this land use. A survey was conducted on a sample of 104 landowners with cattle farms larger than 100 ha. The adoption of forestry in cattle farms was strongly associated with educational level and farm size. The most frequently mentioned *advantage* in forest plantations owners (FF) and farmers willing to adopt forestry (PWF) was the shelter that trees give to cattle, followed by the increase in calving rate. In those cases where more than one disadvantage was mentioned, environmental issues were the main factors constraining plantation forestry adoption. Over 18 % of FF farmers and 37 % of farmers not willing to adopt forestry (NWF) perceived land use conversion from forestry back to grassland pastures and the high costs involved as a major disadvantage.

Keywords Silvopastoral systems · Livestock · Adoption · Forestry · Environment

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Introduction

In Uruguay in the early 1990s a new system of financial benefits and tax exemptions was developed to promote forestry on low productivity soils, most of them on cattle farms. Since then, foreign companies have planted more than 400,000 ha and local landowners have established an additional 150,000 ha on former pasture rangeland (estimated from DI.CO.SE. Database; Sosa Dias, 2013, personal communication). As of 2013, one third of agricultural exports from Uruguay come from forestry. Traditional land use systems include beef cattle production and sheep farming; large-scale plantation forestry is a recent addition to

rural landscapes. Even when silvopastoral systems (SPSs), combining forestry and cattle and/or sheep farming, are perceived as being more diversified, presenting lower economic risks, lower soil erosion and higher biodiversity values (Cubbage et al. 2012) local information on their merits and limitations is lacking.

Many factors may contribute to the adoption of forestry as an innovation among non-vertically integrated landowners. If innovation involves combining forestry with cattle farming systems, an important factor is farm size (Salam et al. 2000; Simmons et al. 2002; Summers et al. 2004), followed by non-resident ownership (Summers et al. 2004) and the farmer education level (Tosakana et al. 2010; Walters et al. 1999). Family group structure and their individual work dedication were also identified as significant factors (Browder and Pedlowski 2000; Walters et al. 1999). Some negative perceptions of SPS adoption may change during the lapse between initial adoption and several years afterwards; the main changes observed regarding difficulties were reductions in the perception that there would not be enough light for pasture growth and the complexity of forest and livestock management in importance, decreasing with respect to initial negative views (Frey et al. 2012). One of the disadvantages perceived as a constraint to forestry adoption, is the cost of project abandonment, mentioned by Mercer (2004) in his review.

The presence of government agents supporting the plantation activity, highly affected the decision of whether to adopt a new activity; the farmers' social environment also had an effect on the innovative activity (Walters et al. 2005). Interactions among farmers, mutual suggestions and advice were relevant when adopting new practices. Farmers who were members of social organization were more likely to afforest in comparison with those who were not organization members (Morris and Potter 1995; Nybakk and Hansen 2008). Farmer's age was not found as relevant factor in adoption, but the education level was (Ferreira 1997); farmers' production objectives do not favour change in the medium term. Their ability to be independent and flexible seems to be of great importance to select or include a new production system; in family systems, the size is the best predictor for technological adoption (Ferreira 1997).

Among other perceived advantages, both before and after SPS adoption, the reduction of cattle heat stress under shade has been mentioned by Frey et al. (2012). Also reduced soil erosion and receiving government incentives have been perceived as positive silvopasture effects (Cubbage et al. 2012).

Inclusion of a new activity in the farm

Getting conservative farmers to adopt innovations like forestry is often challenging, especially if practical and theoretical aspects are unknown.

Surry (1997) described the diffusion-innovation theory as the process in which an innovation is adopted by a certain population of a community depending, among other factors, on the type of innovation and the way it is transmitted (Rogers 2003). An innovation can be a group of new combinations of existing resources taking place in a discontinued way (Schumpeter 2008) or it can be a mere improvement of a process or an existing product. The non-linear aspects of introducing new practices are one of the most important characteristics of an innovation system approach (Fragerberg et al. 2006).

The objectives of this study were identifying the main factors affecting the adoption of commercial forestry in cattle farms and assessing cattle farming and forestry integration potential.

Materials and methods

The region studied in Uruguay consisted of four zones, representing 83 % of total soil types suitable for forestry (over 4:056.000 ha; Dell'Acqua, personal communication, November 2010) and 57 % of total cattle farming land (more than 12:200.000 ha): Western (WZ), Central (CZ), Eastern (EZ) and Tacuarembó (TZ).

Cattle grazing area and the number of cattle ranches with more than 100 ha were computed for each zone on the basis of official records, provided by DI.CO.SE. (Sosa Dias, 2010, personal communication), and forestry priority soil areas. Some categories were over sampled; this led to an adjustment of the original sampling error (5 %) which finally increased to 7.1 %.

Landowners were considered forest growers if they had woodlots comprising about 8 % or more of the ranch area under commercial forestry. Farmers who had only established woodlots as windbreaks,

shelterbelts or shade were excluded from the study. Cattle ranchers with no forest plantations were included in the sample only if their farms had at least 8 % of land surface with soil types suitable for forestry.

The study was held from 2010 to 2011 in two stages. The first part consisted of 32 semi-structured interviews to several types of key informants, including decision makers, farmers' union leaders, agricultural technicians, agronomists, policy advisors and cattle farmers well respected among their peers. The aims of this phase of fieldwork were to identify elements emerging spontaneously during the interviews and to identify relevant variables (Mendizábal 2006).

The second stage involved structured personal surveys, integrating variables identified during the first stage. Surveys were held individually with 106 cattle farmers; two of these had been initially selected by mistake (e.g. one was a dairy farmer, another was not a landowner but a tenant) and were therefore omitted from the sample, which resulted in 104 valid surveys.

The survey form consisted of 42 questions, grouped into the following subsets: (a) sociological characteristics, such as landowner age and family structure, farm residency status and knowledge on the financial benefits of forestry; (b) farm characteristics, like size, production related activities (livestock farming, agriculture and forestry) and ranch productive specialization (cow-calf, winter fattening and full cycle); and (c) a ranking of advantages and disadvantages of adopting forestry, classified in four categories (productive, economic, environmental and any other the respondent could identify) (Fig. 1).

The questionnaires covered two strata of farmers—(1) landowners of 100–500 ha and (2) more than 500 ha (Table 1) and each stratum was divided into cattle farmers with forest plantations (FF) and cattle farmers without forests (Non-FF).

These four subcategories were sampled proportionately, based on the total population of cattle ranchers in each region (Table 1).

Data were processed using Stata/SE 14.0 software. Average values and standard deviation of sociological and production-related variables were computed.

The relationships between forestry adoption and each of the sociological variables and one farm characteristic variable, viz. (a) educational level (1-up to elementary school or incomplete secondary education 2-up to secondary education or incomplete tertiary education and 3-complete higher education) (b) age, (c) number of children, and (d) area owned by cattle rancher were assessed with Fisher's exact test, because number of observations among categories were quite dissimilar and some of the categories had less than five observations. The association between forestry adoption and production-related activities was assessed using the Chi square test. Finally, the relationship between forestry adoption and the farm size was tested using independent group *t* test.

Once the sample was processed, population parameters of number of landowners and potentially afforestable areas, combining soil aptitude and landowner willingness, were estimated. The average population estimates ($\bar{y}_{est}$) were calculated as described by Cochran (1972),

$$\bar{y}_{est} = \sum_{h=1}^{H} y_h W_h \quad (1)$$

where Y_h is the stratus estimated mean, Wh is the N_h/N Proportion of each stratus. Subpopulation size of a stratus (N_h) divided into the total population size (N).

In the same way, the population proportion ($\hat{P}_{est}$) estimated from the simple proportions of each of the strata ($\hat{P}_h$) was computed as follows,

$$\hat{p}_{est} = \sum_{h=1}^{H} \hat{p}_h W_h. \quad (2)$$

No previous local work is known where the whole universe (the complete population database) has been available to be sampled, as is done here. This enabled a highly accurate estimation of population parameters through sampling, after superimposing land ownership with soil type and land use suitability.

Results

The first stage of interviews to key informants yielded the following topics, summarized in Table 2.

From the 104 answers to the survey questionnaire, three sub-samples were defined, viz. (a) farmers who had adopted silvopastoral systems (SPSs). The subsample of cattle ranchers with no plantation forestry on their ranches (Non-FF) was further divided into (b) cattle farmers potentially willing to afforest (PWF) and (c) not willing to afforest (NWF).

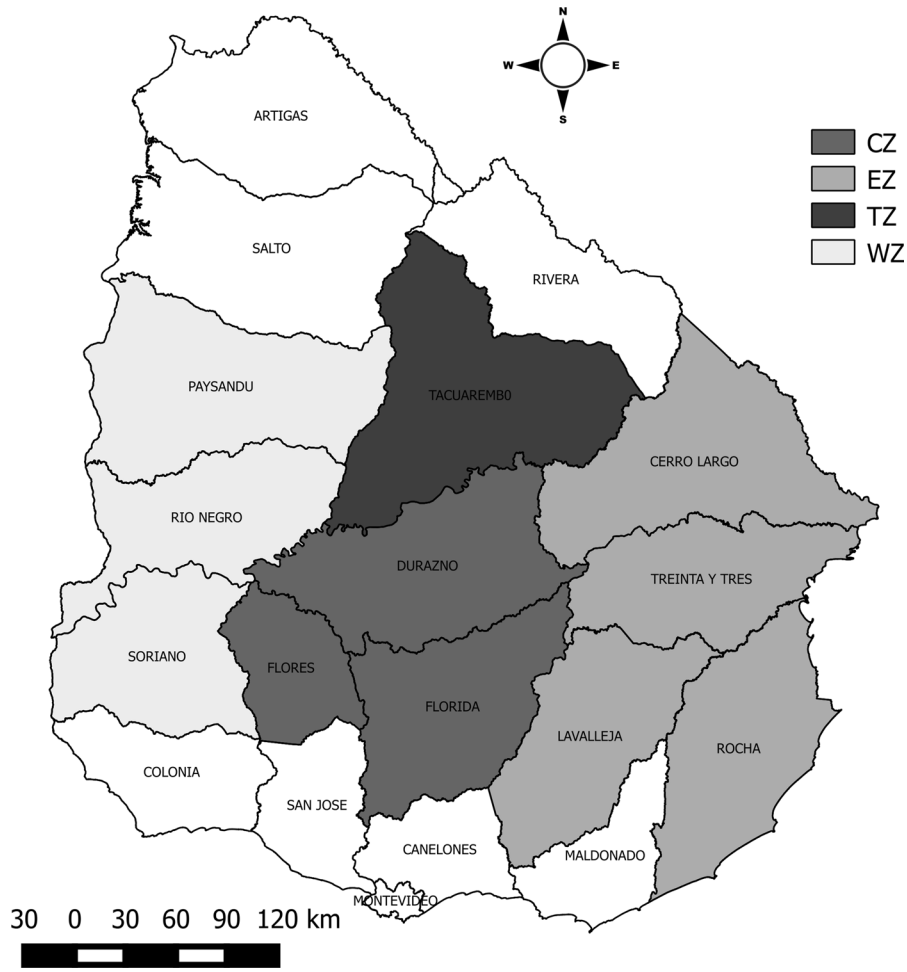

Fig. 1 Zones in Uruguay

Table 1 Number of cattle ranchers in the sample

Zone	Number of farmers	Ranch size range (ha)			
		100–500		>500	
		FF	Non-FF	FF	Non-FF
Western	31	5	10	8	8
Central	33	6	9	8	10
Eastern	27	5	13	4	5
Tacuarembó	13	3	7	0	3
Total	104	19	39	20	26

Sample description

The average age of the farmers was 54 years (s.d. = 12); the household averaged 2 children (s.d. = 1.4), with an average age of 22 years. 25 % of the cases had one or more children working on the farm. The producer lived on the property in 42.8 % of cases. Although in most cases the household lives in a nearby population center, the producer usually spent most of the week on site. Most producers specialized in one phase of livestock production (36 %), while in some cases producers managed the full cycle of cattle raising (33 %).

Table 2 Summary of key informant interview primary results

Factors furthering the adoption of forestry	Access to grazing in management units owned by forest companies, Diversify production activities (wood, rural carpentry, etc.), Use of marginal farming lands for forestry, shade and protection against wind available, Increasing asset value of land
Production-related issues which could constrain forestry adoption	Higher level of cattle management complexity, Reduction in cattle stocking rates and grazing areas, Landscape alteration, Higher incidence of livestock disease
Sociocultural issues which could constrain forestry adoption	Uncertainty of timber marketing, Lack of knowledge on how timber markets operate, lack of knowledge on working agreements with forest companies, cattle rancher age
Environmental issues which could constrain forestry adoption	Land use change, Loss of native grassland pasture, Water inadequate in quality or quantity in forested catchments, Denser populations of potentially damaging wildlife (foxes, wild boars)
Research and information needed	Management of beef cattle categories through different forest component phases, Beef cattle supplementary feeding, Effects of shadow and shelter against winds on animal well-being and performance, Land use change
Externalities due to the adoption of forestry	Rural road deterioration

Table 3 Educational levels and adoption of forestry among cattle farmers with forest plantations (FF—1) or without forest plantations (Non-FF—0)

Educational level	Forestry adoption		Total
	0	1	
1	29	4	33
2	22	11	33
3	15	23	38
Total	66*	39	104

* Significant differences at the $P < 0.05$ level using Fisher exact test

The relationship between three educational levels and forestry adoption is shown in Table 3. The adoption of forestry in cattle farms was strongly associated with educational level if all four zones are analyzed as a whole. This still holds true in Western and Tacuarembó Zones (Significant differences at the $P < 0.05$ level using Fisher exact test). In the Eastern Zone, the relationship was non-significant (Fisher exact test, $P = 0075$). In contrast, no such connection could be established in the Center Zone (Fisher exact test, $P = 1000$).

Average farm size values for each sub-stratum are shown Table 4. A significant relationship between farm size and the adoption of forestry ($P > 0.05$) was found; this would indicate a general tendency of adopting forestry when cattle farm area is larger, except in Tacuarembó, where no FF landowner with a farm of more than 500 ha could be included in the sample. Also within the 100–500 ha range stratum, the FF farmers in the Central Zone had smaller estates than Non-FF farmers.

No significant relationship could be established between cattle ranch productive specialization (cow-calf, winter fattening and full cycle operations) and forestry adoption (Table 5). In each analysis, only farmers who could define their operations as either "cow-calf", "winter fattening" and "full cycle" were set apart from the rest; in four cases, farmers could not define a clearcut productive specialization profile.

Advantages and disadvantages identified by farmers who had adopted SPSs

Approximately 56 % of farmers who had already adopted silvopastoral systems (FF) were aware of contract opportunities that large forest companies provide. Most of them (67 %) had established plantations on their own, while only 18 % planted in association with forest companies. The remaining 15 % established the plantation through loans or forestry law subsidies. Forest plantation area per farm ranged from 118 to 244 ha, with a weighted average value of 181 ha (s.d. ± 63).

The foremost *advantages* of forest trees identified by FF farmers were production- related: shade in summer and protection from winds in winter, listed by 56 % of the FF respondents (see Table 7). The advantage most mentioned as second in importance (28 %), was the better use of marginal soils, which are less productive for cattle grazing purposes; better land use would be thereby achieved. Next in decreasing hierarchical order were the increase in calving percentage (21 % of FF respondents) and access to grazing in areas managed by large forest companies (8 %).

Within *economic advantages* of plantation forestry identified, the most frequently mentioned was the

Table 4 Average area (ha) of farms in each ranch size stratum and sub-stratum (FF/Non-FF)

Zone	Average ranch size (ha)					
	FF	Non-FF	100–500		>500	
			FF	Non-FF	FF	Non-FF
Western	1045	646.5	319	232	1498.8	1164.6
	(726.3)[a]	(768.4)	(102.7)	(143.1)	(535.1)	(924.9)
Central	991.4	695.9	227.5	348.4	1646.2	993.6
	(922.1)	(451.5)	(53.2)	(77.0)	(783.6)	(439.3)
Eastern	637.5	475.6	233.6	228.4	1142.5	1064.0
	(507.2)	(476.5)	(142.0)	(141.8)	(217.4)	(541.9)
Tacuarembó	401.6	537	401.6	254.3	–[b]	1114.6
	(140.6)	(427.5)	(140.6)	(112.3)		(223.2)
All zones	879.4*	596.7	280.6	260.3	1478*	1073.7
	(741.8)	(555.4)	(119.2)	(130.1)	(600.15)	(604.5)

[a] Standard deviation

[b] In the case of Tacuarembó Zone, no cattle farms with areas larger than 500 ha where forestry had been adopted could be included in the survey

* Statistically significant differences using independent group *t*-test ($P < 0.05$)

Table 5 Relationship between ranch productive specialization and forestry adoption (FF-1/Non-FF-0)

Forestry adoption	Cattle ranch productive specialization (*n*)					
	Cow-calf	Winter fattening and full cycle	Winter fattening	Cow-calf and full cycle	Full cycle	Cow-calf and winter fattening
0	31	35	8	58	23	43
1	18	20	6	32	14	24
Total	49	55	14	90	37	67
Significance	$P < 0.969$		$P < 0.598$		$P < 0.838$	

Relationships were tested using the Chi square test

diversification of income sources (77 % of the FF respondents); in second place came land value increase (13 %). Even when qualified informants pointed out wood production for rural carpentry as a relevant topic, it was not mentioned by farmers even once when answering survey questionnaires.

Among the *disadvantages* of SPS adoption, higher fire hazard rates was the most frequently mentioned (33 %), followed by the difficulty of reverting soil to its natural grassland condition after forestry (18 %). Third in rank (13 %) is the threat of dangerous wildlife, specifically in sheep ranches.

Advantages and disadvantages identified by farmers who had not adopted SPSs

Landowners willing to adopt forestry

Advantages identified by FF and PWF farmers were quite similar. In the group willing to afforest (PWF), the most frequently mentioned *advantage* was the shelter that trees give to cattle (96 %), followed by the increase in calving rate (9 %). In those cases where more than one disadvantage was mentioned, environmental issues were the main factors constraining plantation forestry adoption. For PWF respondents, the most relevant *environmental disadvantage* was, the presence of wildlife (47 %), followed by the variation in the soil water levels (13 %), soil fertility loss (13 %) and higher fire hazard rates.

Other disadvantages perceived are the reduction of grazing areas (22 %), mainly during the first year of forest plantation life, health issues for cattle grazing under forest cover—e.g. toxicity symptoms due to ingestion of *Clavaria* or *Ramaria* genus fungi fructifications, often found in *Eucalyptus* plantations. Finally, the main economic disadvantage of forestry identified by this set was the long period of investment return.

Landowners not willing to adopt forestry

The main constraint types identified by farmers not willing to adopt forestry (NWF) were production-related (51.2 %), environmental (27.9 %) and

economic (18.6 %), as first, second and third most relevant disadvantages, respectively.

If respondent answers are further analysed within constraint types (Table 6), an apparent contradiction arises between what NWF farmers mentioned as most relevant categories. At first, production-related constraints were the highest ranked; when frequencies were computed, one issue classed as environmental was understood by these farmers as a production-related constraint. The placement of this constraint in one or the other type group could be to some extent debatable; on one side, conversion costs of land use change from plantation forestry to grassland pasture can be related to environmental liability. On the other hand, potential adopters usually perceive forestry as an alteration of the original cattle husbandry operation, i.e. a production-related constraint.

Conversion of land use from forestry back to grassland pasture was identified as the most important drawback of forest plantations by 37.2 % of the NWF farmers; soil water level variations were mentioned by 30.2 % of these respondents. The increase of potentially damaging wildlife and higher fire hazard rates were considered relevant only by NWF farmers in the Central and East Zones and ranked third and fourth, respectively within their constraint type.

Among production-related constraints, most frequently mentioned was the reduction in cattle stocking rates and grazing areas, in particular during the first years of forest plantations (39.5 %), followed by higher incidence of livestock disease (9.3 %) and lack of knowledge on forest plantation management (7 %). The two latter constraints were only relevant for farmers in the East and Tacuarembó zones.

Among environmental issues, the most mentioned overall were soil fertility loss (45 %), soil water level variations (41 %), the increase of potentially damaging wildlife (18 %), and in a lesser extent, higher fire hazard rates (14 %). Only Eastern Zone NWF farmers ranked the rise of fire hazard rates and landscape alteration as important drawbacks; however, they still were listed as less important than economic constraint.

Relevant economic constraints most frequently referred to were the long period of investment returns in forestry (34.9 %), and high initial capital investment in forestry, related to plantation establishment costs and initial tending (18.6 %). Some NWF farmers (20.9 %) could not identify relevant economic constraints, of which only 9.3 % ranked this first.

Advantages and disadvantages identified by all 104 respondents are summarized in Table 7. Note that NWF farmers were not inquired on the advantages of adopting forestry, they were only asked about the disadvantages they identified.

Views on forestry and forestry adoption potential

Forty-one percent of questionnaire respondents belong to some kind of farmers association. These farmers were asked about the opinion, image or perception that their association had regarding forestry. Thirty-one percent said their association had a favourable opinion, 38 % stated that they ignored where their association stood on forestry and an additional 10 % declared association indifference or no opinion whatsoever, while 19 % reported a negative view.

The understanding of governmental incentives to forestry adoption was also assessed. Only 29 % of respondents were aware of tax benefits granted through Decree No. 191/006 (MGAP 2006), specifically devised to promote the adoption of forestry in cattle farms.

This study covered an area of 6.9 million ha, 55 % of the total rural land surface in Uruguay. Within the four zones, almost 3.4 million ha are classed as soil types suitable for forestry (83 % total forestry-suitable land area; see Table 8). The study includes 358,000 ha of forest plantations owned by non-integrated companies and 9305 cattle farmers (53 % of landowners with farms larger than 100 ha). The land owned by the 104 respondents include a total area of 37,927 ha (MGAP 2010).

The total number of cattle farmers likely to adopt forestry was estimated as 2848, with a distribution within farm size strata which is peculiar to each zone (Fig. 2). The small farms group without afforestation is the most important, since the EZ is the one that presents the largest area of farms with possibilities to afforest.

Willingness of farmers to adopt forestry

Out of 65 farmers, 23 (35.4 ± 0.8 %) answered that they were willing to establish forest plantations (PWF), equally distributed among small and medium farm size strata. Farmers in the Central Zone had the highest percent disposition to adopt forestry, both in

Table 6 Nature, description and distribution of constraints to forestry adoption

Type of constraints identified	Description	Zone			
		WZ $n = 13$	CZ $n = 9$	EZ $n = 16$	TZ $n = 5$
Environmental	Conversion of land use from forestry back to grassland pasture	**1**	2	**1**	**1**
		7	3	7	2
	Soil water level variations	2	**1**	**1**	**1**
		4	4	7	2
	Increase of potentially damaging wildlife	–	3	2	–
		0	2	6	0
	Higher fire hazard rates	–	4	3	–
		0	1	5	0
Production- related	Cattle management alterations in stocking rates and grazing areas	**1**	**1**	**1**	**1**
		5	5	5	2
	Higher incidence of livestock disease	–	–	2	2
		0	0	3	1
	Lack of knowledge on forest plantation silviculture and management	–	–	3	2
		0	0	2	1
Economic	Long period of investment return in forestry	**1**	–	**1**	**1**
		5	0	8	2
	High initial capital investment in forestry	–	2	2	2
		–	2	5	1
	No economic constraints could be mentioned	2	**1**	3	–
		4	4	1	0

Upper line of digits to the right of constraint description indicate ordinal place within each type identified in a given zone

Lower line of digits to the right of constraint description indicate number of farmers who mentioned it in a given zone

Bold number indicates the first constraint mentioned

small (42 %) and medium (45 %) farms, followed by Tacuarembó Zone and Western Zone, where 33 % of small farm owners and 27 % of farmers were willing to adopt forestry, respectively.

Farms managed by landowners willing to adopt forestry had an average area of 322 ha for small, and 1066 ha for medium owners (Table 9), with a total average area of 558 ha.

Small and medium-scale landowners would be willing to afforest 46 (13.6 %) and 295 ha (25.1 %) of total ranch areas, respectively (Table 10), with an average proportion of 24 % (±11 %).

Farms in the East Zone have the highest potential, in spite of the lowest proportion (17 %, see Table 9) of PWF farmers, because of the extensive areas of soil types suitable for forestry, The average farm size owned by NWF farmers is 543 ha (±55); this group represent 71 % of the medium-size stratum and 89 % of the small-size stratum.

Total area for potential adoption of forestry is 101,150 ha (±33,273), considering all four zones and both farm size strata.

Discussion and conclusions

The entire study area represents a wide range of social and economic situations. The Western Zone had the highest integration levels among production systems; the Eastern Zone has de largest amount of small farms (<500 ha). Some of these relationships could be established in general terms but could not be confirmed statistically within all zones.

Social issues

Farmer educational level and forestry adoption were related, as reported by Tosakana et al. (2010) and by

Table 7 Summary of main advantages and disadvantages identified by survey questionnaire respondents

Advantage/disadvantage described	Forest plantation owners (FF)	Farmers without forest plantations	
		Willing to adopt forestry (PWF)	Not willing to adopt forestry (NWF)
	$n = 38$ (%)	$n = 23$ (%)	$n = 43$ (%)
Production-related advantages			
Trees provide shade in summer and shelter from winds in winter to cattle	56	96	
Better use of marginal soils	28		
Increase in calving percentage	21	9	
Access to grazing in areas managed by forest companies	18		
Production-related disadvantages			
Cattle management alteration in stocking rates and grazing areas			40
Higher incidence of livestock disease			9
Lack of knowledge on forest plantation silviculture and management			7
Environmental disadvantages			
Conversion of land use from forestry back to grassland pasture	18		**37**
Increase of fire hazard rates	33		
Increase of potentially damaging wildlife	13	47	
Soil water level variation	5		30
Economic advantages			
Diversification of income sources	77	57	
Land value assets increase	13	30	
Economic disadvantages			
Long period of investment return in forestry			35
High initial capital investment in forestry	26		
No economic constraints could be mentioned			9

Bold number indicates the first constraint mentioned

* Disadvantages for NWF appear in a hierarchical order

Table 8 Soil types suitable for forestry in cattle farms

Zone	Soil types suitable for forestry (ha)	Cattle farming area (ha)	Percent (%)
Western	613,470	3,041,947	20
Central	587,053	2,655,690	22
Eastern	1,783,275	4,208,231	42
Tacuarembó	374,529	1,550,004	24
Total	3,358,327	11,455,872	29

Walters et al. (1999); however, differences between the four zones were observed. The Western Zone has the highest complete tertiary level (50 %). In the Eastern Zone, a high proportion of the farmers (49 %) had completed elementary education. Educational level could possibly be related to access and interpretation of complex issues, such as information concerning environmental hazard, e.g. the impact of forestry on water supply and quality. Even when some research has been done on forestry and the environment in Uruguay, dissemination of these topics is quite scarce.

A significant link between forestry adoption and farmer family structure (number of children and their ages) could not be established, as reported in literature (Browder and Pedlowski 2000; Walters et al. 1999). Also the relationship of forestry adoption with farm residency

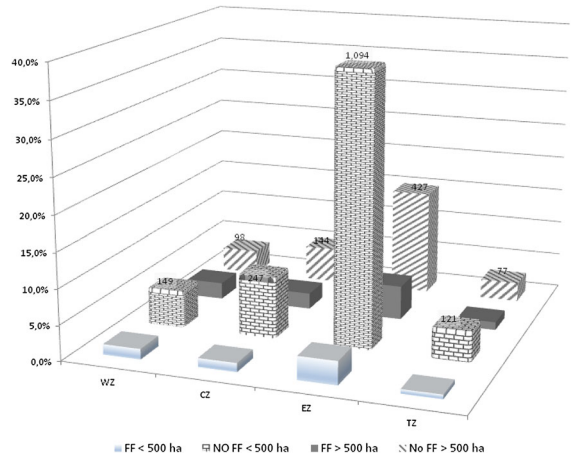

Fig. 2 Population distribution of cattle farms with soil types adequate for forestry. *Note* FF are cattle farmers owning 8 % or more of farm surface as forest plantations; Non-FF are cattle farmers with no forest plantations

Table 9 Average area of farms owned by PWF farmers

Zone	<500 ha	*n*	>500 ha	*n*
Western	292.5 (88.38)[a]	2	778 (248)	3
Central	368 (77)	5	974 (592.56)	5
Eastern	400	1	1575 (530.33)	2
Tacuarembó	259 (144.68)	4	1372	1
Average	321.75 (108.13)		1066.18 (520.70)	

[a] Standard deviation

Table 10 Average area which farmers willing to adopt forestry

Zone	<500 ha	>500 ha
Western	15	150
Central	66.2	135
Eastern	50	600
Tacuarembó	53.3	–
Average	46	295

status (as in Summers et al. 2004) or with membership of social organizations (Morris and Potter 1995; Nybakk and Hansen 2008) could not be ascertained.

Farm size appeared to be related to forestry adoption, as reported by other authors. However, average farm size in these studies differs greatly from present research, ranging from 4 ha (Murinati et al. 2001) to 81 ha (Summers et al. 2004). As could be expected, the proportion of PWF farmers is high (25 %) among those landowners managing farms larger than 500 ha.

Advantages and disadvantages of forestry

The most relevant production-related advantage identified was shade in the summer, both for FF and PWF farmers, as noted in previous work by Cubbage et al. (2012) and Frey et al. (2012). In the latter, a set of farmers equivalent to our PWF group mentioned reduced stress of cattle because of shade as an important advantage and had the same opinion several years afterwards, when they had already adopted forestry and thus become similar to our FF group. This advantage should be taken into account during design of woodlots and SPSs, as both shade and timber production would have to be optimized for best results.

The second most important factor was an advantageous use of soil types marginal for beef cattle grazing purposes. Also some areas within forest plantations, such as firebreaks, trails, access roads and roadside may be grazed reducing fire hazard, which results in better land use and livestock management.

On the other side, some disadvantages are perceived by 18 % of FF farmers and 37 % of NWF concerning land use conversion from forestry back to grassland pastures and the high costs involved, a drawback also reported by Mercer (2004).

Cattle management alteration in stocking rates and grazing areas was the production-related disadvantage most often mentioned by NWF farmers.

Economic advantages of adopting forestry most commonly mentioned by both FF and PWF farmers were the diversification of income sources and land value assets increase. Most frequently mentioned economic disadvantages were the long period of investment return and high initial capital investment in forestry. Even though 26 % of FF farmers mentioned the latter and complained about the lack of funding, most of them had financed forest plantations using their own resources. A fraction of NWF farmers did not identify any economic constraints to forestry adoption.

The increase of fire hazard rates was an environmental disadvantage often mentioned by FF farmers in all zones. Also important was the increase of

potentially damaging wildlife; the concern of many cattle farmers is a denser population of feral boars attacking sheep flocks and the increase in fox numbers. A frequent environmental concern in the Western Zone were the changes in soil fertility resulting from the adoption of forestry. Soil fertility loss could become a daunting problem in the context of agricultural expansion, reducing available cropping land area; in fact, soil fertility for forest tree species is less of a problem than for grasslands, pastures or crops. PWF farmers are worried by potentially damaging wildlife and also by reduction in soil water levels as a result of forestry, especially in Tacuarembó and Central zones. This could be related to the fact that in both zones extensive beef cattle husbandry is combined with sheep breeding and raising. Factors cited by respondents as environmental constraints are actually environmental impacts of forestry affecting original livestock operations and can be also considered, to a certain extent, to be production-related. However, PWF farmers in TZ and CZ are frequently inclined to adopting forestry, on the basis of shade and shelter for livestock benefits, and are possibly willing to afforest 21 % of farm area.

It is worth noting that 56 % of respondents were fully aware of the opportunities offered by forest companies through working agreements and technical assistance; even so, only 18 % have adopted forestry by way of such contracts.

Production-related constraints are the most relevant for NWF farmers, especially in the Eastern Zone, where farm sizes tend to be smaller. The difficulties and high costs involved in the conversion of land use from forestry back to grassland pasture was the second most mentioned issue.

Most respondents were not aware of a governmental decree granting subsidies to plantation forestry on suitable soil types; this fact may stem from insufficient communication, since well-informed farmers were very few indeed.

There is a great potential for the adoption of forestry in beef cattle farms; over 100,000 ha could be used for woodlots or SPSs. The combination of forestry and beef cattle production could be very successful, owing to low product price correlation. If forestry were adopted, farmers could benefit from independence of market prices, reducing the risk of low payments.

The most challenging obstacles yet to be overcome by NWF farmers are the comprehension, integration and articulation of silvopastoral systems. Perhaps the most important constraint is the lack of knowledge and the perception of forest plantations and beef cattle husbandry as inordinately complex. Unfortunately, the Eastern Zone, with the best potential for forestry adoption is located the farthest from forest industries and pulp mills.

Overall, this research found that there were many reasons for producers to increase their forest area, and that benefits such as shelter, dual cattle and tree income sources and use of poor pasture land were important. Diverse production-related, social and economic conditions could be acting as constraints to forestry adoption in cattle farms. More government incentive payments or higher rates could increase tree planting, and forestry companies could foment silvopasture on farmer lands by covering some establishment costs, or making lease payments for forest on those lands.

Better timber markets and prices also could help encourage adoption as the new pulp mills increase production. More research that helped documenting the severity and reducing the threats of forest health, wild animals, water scarcity and others also could promote the adoption of silvopasture systems. Last, more extension about the perceived versus actual benefits and limits of SPS could help famers make better decisions regarding adoption of this new technology, and help improve farm incomes and environmental protection. We are continuing to pursue this line of research on economic and environmental issues, and hope to contribute more knowledge to these subjects as well.

Acknowledgments The authors would especially like to express their gratitude to CSIC (Scientific Research Sectorial Committee) University from Uruguay (UDELAR) for the funding of this research project, and to Forestal Oriental S.A. for the financial assistance given and for valuable suggestions made by Andrés Solari, Nicolás Mosca and Alexander Burger.

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