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Land cover and land use changes in relation to social evolution—a case study from Northern Chile

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Abstract

In the Chile's Choapa valley (4th Region), the small-scale irrigated agriculture found today was brought about by the changes in land tenure which occurred between 1965 and 1975. In the Chillepin district, an extensive holding that produced wheat and cattle was expropriated and, after a period of collective farming, small family holdings of vineyards and orchards took their place. These changes were studied over a 50 years period through the use of social enquiries, local history, vegetation measurements and aerial photographs so as to compare the effects of the successive agrarian systems on the environment. The most intense wood extraction occurred during the 8 years' period just after the expropriation. During 25 years of small family farming we observed that (i) diversity and number of cultivated plots in the irrigated area have increased and (ii) tree vegetation in the hinterland has partially recovered. The first is due to the know-how of the peasants, who agreed to specialize in grape production as the market became assured, but who have managed other productions in mixed farming using few chemicals and the traditional irrigation system. The second effect, in the mountainous hinterland, is mainly due to (1) the termination of rain farming and charcoal production, (2) the slowing down of the deforestation for fuel-wood and (3) the controlling of the perimeter as private property.

Keywords: Social evolution; Land use; Vegetation; Deforestation; Family farming; Semi-arid climate; Environment; Northern Chile

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1. Introduction

Desertification is a term commonly used for the northern part of Chile. Authors have described a severe land degradation as the result of inappropriate cultivation practices, goats and sheep overgrazing, woodcutting and agrarian systems inherited from past colonial periods (Cunill, 1971; Bahre, 1974; Aschmann and Bahre, 1977, pp. 73–84; Fuentes and Hajeck, 1979; Fuentes and Muñoz, 1995). But the social and historical aspects of this ecological problem were probably not completely envisioned as it is now admitted that traditional land use is far to being a cause of land degradation. To the contrary, in densely populated and intensely cultivated areas such as the Bamileke region in Western Cameroon (Fotsing, 1995, pp. 131–148) or the central plateau in Madagascar island (Blanc-Pamard et al., 2000; Locatelli, 2000), land preservation is intimately related to human practices and social behaviour. The efficiency of traditional techniques to prevent erosion and maintain soil productivity, including livestock breeding, mixed farming, trees and quickset hedges, is generally ensured through social practices such as the unique successor and the regulation of the relationships between farmers and breeders. In a stable social context, adaptive strategies develop their own response to cope with socio-economic difficulties. For instance, in North Eastern Nigeria, peasants have shown adaptive strategies in response to drought, problems in livestock management and food supply (Mortimore and Adams, 2001) and also in response to the reduction of the floodplain downstream of a dam (Thomas and Adams, 1999). Nevertheless, when the strong group rules and the traditions, generally enforced by elders, are undermined by social changes due to population displacements, new cultivation techniques, new land owners or high urban demand, the stable combination of land use with social traditions is disrupted and the pressure of the new ways of making use of the local resources carry along to land degradation. In some cases this may lead to desert conditions as occurred in Northern Kenya (Kasusya, 1998). In a context of social instability, poverty and unsafe conditions affecting particular groups may also have drastic consequences on the environment (Blaikie et al., 1994). Social upheavals have affected the 4th Region of Chile and specially the Choapa river upper valley when dramatic changes of land property occurred during the last 50 years. First, vast real estates (*fundos*) established during the colonial period were expropriated between 1965 and 1967 by the Agrarian Reform of the Frei government. Just after a collective farming system regrouping the ex-workers of each expropriated fundo was installed. In 1975, in the first years of the military regime, the Counter Reform introduced the private property through land attributions, thus creating small-scaled family farming entities. As the region endured two social upheavals during the last 50 years, three periods were discerned in this study: (1) 1950–1967, the last moments of the Chillepin *fundo*, (2) 1967–1975, the collective organization period starting with the expropriation of the *fundo* and ending with the setting up of the family farming, and (3) 1975–1999, the 25 year long evolution of the family farming.

Through the example of the Chillepin district we will examine the land management practices, the rate of deforestation, the irrigation network, the population and the land tenure during the three above-mentioned periods in order

to obtain an accurate explanation on how the land-cover degradation has occurred. We will also evaluate the effects of the family farming on the social stability and the environment.

2. Study area, methods and materials

The study area is the rural district of Chillepin in the Salamanca commune. The district presently includes 1377 ha irrigated by canals and 18 923 ha of mountainous land culminating at 3000 m (Fig. 1). Its limits match exactly with the territory occupied 50 years ago by the 'fundo Chillepin', an extensive private property of 20 300 ha. The climate is semi-arid with an average annual rainfall of about 250 mm and high inter-annual variations (Fig. 2). Rainfall data proceed from the weather station of Cuncumen, 15 km to the East of Chillepin (Dirección General de Aguas, 2001). The Rio Choapa begins its course in the snowy high cordillera, close to Argentina, and never dries out. Its waters irrigate the main valley of the study area. Two intermittent rivers, or wadis, also cross the area: the 'rio Gualtatas' and the 'rio Manque'. They flow only from July to September, but small ponds persist until March or April. In the rangeland, the natural vegetation is the matorral (Rundel, 1981), a 0.5–1.5 m high shrubby vegetation mainly composed of *Colliguaja odorifera*. Trees (*Lithraea caustica*, *Quillaja saponaria*, *Acacia caven*) are 2–3 m high and scattered 10–25 m apart on the southward slopes. Up to an altitude of 2000 m tree species are *Kageneckia angustifolia*, and more scarcely *Prosopis chilensis*. On northward slopes more exposed to the sun, trees are replaced by cactus (*Eulychnia*

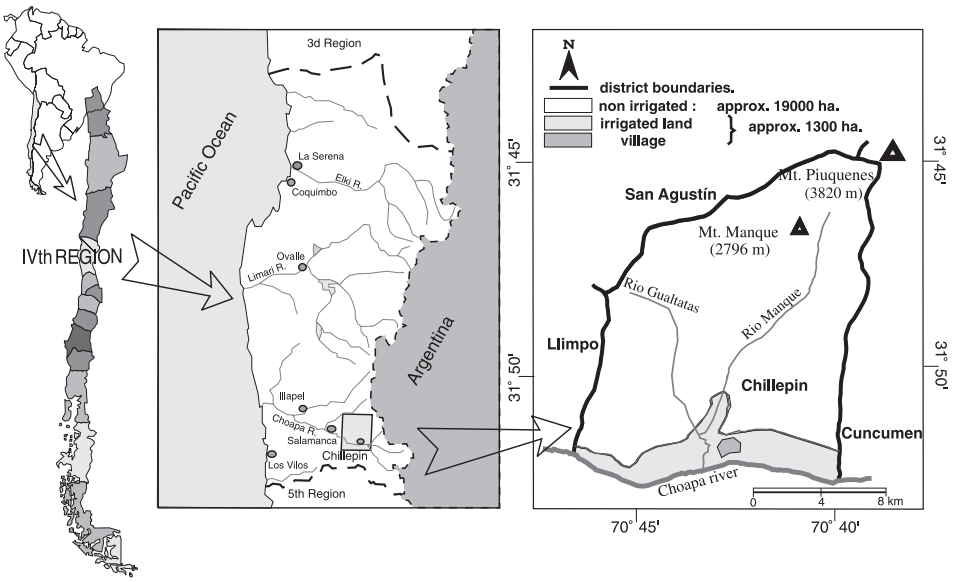

Fig. 1. Location map.

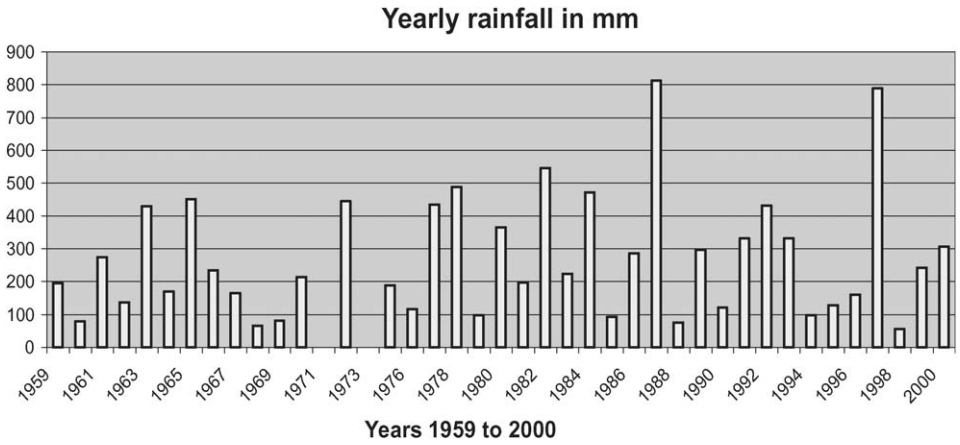

Fig. 2. Rainfall distribution in the weather station of Cuncumen (S 31°54′00:W 70°37′00) during the 1959–2000 period.

acida, *Puya verteroniana*). In valley bottoms the tree stratum (*Quillaja saponaria*, *Maytenus boaria*) is higher and denser. Geology depends on the altitude. From the level of the main valley of Chillepin, which is about 1000–1800 m is the granite basement. It is a pale coloured rock, intensely weathered into boulders within a sandy matrix and covered by red clayey Mediterranean soils (Pouget et al., 1996). Above 1800 m are the Andean sediments, essentially sub-horizontal beds of tectonized pelites and andesites, crossed by late volcanic intrusions. These materials are massive, of dark red colour and support shallow soils. Aeolian deposits are scarce or absent.

Different type of data source including aerial photographs, enquiries, oral histories and official records were used as an approach (Dahlberg and Blaikie, 1999) for bringing understandings of social changes and of people's interaction with the environment.

Demographic and agronomic background information on the Chillepin district and the Salamanca commune proceeded from the INE (1952, 1960, 1970, 1982, 1992) national census of population and from the INE (1964, 1975, 1997) national census of agriculture and breeding (INE, National Institute of Statistics, Santiago, Chile).

The first enquiry, named EDA 1998, was conducted in 1998 and concerned the whole population of the Chillepin district: 1150 inhabitants in 302 households. The questionnaire included four modules. (1) Household: economics, family income, commercial or agronomic activities; (2) land tenure: first acquisition of land and house, other acquisitions, present situation; (3) individuals: family composition, migrations of the family head, migrations of the descendants; (4) local history: oral histories of the family heads who were ex-workers of the 'fundo' 50 years ago and of persons who were in charge of the collective agriculture during the Agrarian Reform. The second inquiry, named EDP 2000, was conducted in 2000 and dealt with past and present intensities of the deforestation. Information was reported from four

persons: three lumbermen who worked in the area 30 years ago and are still working today and one person who worked as lumberman for the 'fundo' and nowadays as patrol for the protection of the rangeland. The third inquiry, named ECE 2000, was conducted in 2000 on a sample of 100 households and dealt with domestic consumption of energy.

The vegetation was measured in the field within 25 m wide square plots, located in representative plant formations. Plant cover, number of plants, plant species and phytovolume were determined for each plot. Twenty-two field plots were used to correlate their phytovolume with their normalized differential vegetation index (NDVI) from a Spot image of January 1998. The correlation was then used to establish an image of phytovolume values from 6000 to 30 000 m^3ha^{-1} on the whole area. This image clearly showed remainders of natural sclerophyll shrub vegetation. Details on this subject were published in a previous paper (Alvarez et al., 2002).

Three sets of aerial B&W photographs covering the Chillepin district approximately at scale 1/75 000 and of March 1956, January 1977 and February 1997 were accessible from the Chilean Air Force in Santiago. Additional aerial colour photographs of the irrigated area were shot to grasp exactly the 1999s land use. The conventional B&W photographs were visually interpreted. The land use was interpreted by comparing the soil reflectance on the photograph with the probable crops that existed on the zone at the date the photograph was shot. The maps were geographically adjusted using as reference the topographic map 3145–7030, Cuncumen, 1/50 000 (IGN, Santiago de Chile). The land use was determined at three different dates: 1956, 1977 and 1999. The maps allowed comparisons through time but they did not fit exactly with the above-mentioned historical periods as the 1977 map featured the beginning of the family farming and the 1999 map featured the present state of the family farming. We had no aerial photograph for mapping the collective farming period, which remains poorly documented as compared with the two others.

3. Results

3.1. 1950–1967, the last moments of the Chillepin fundo

At the beginning of the 1950s, Chillepin was a vast farming enterprise called *fundo* of some 20 300 ha. An appointed manager was in charge of the *fundo*. The peasants who worked on the domain (*peones*) owned no land. Some of them (*inquilinos*) had the right to build a house and work a small plot in exchange for a part of their production. In 1952 were registered on the *fundo* 973 individuals from 150 families (Table 1), the majority living in the Rio Manque valley. The permanent staff lived on the *fundo* house, nearby where is now the village school.

In 1956 a new private owner bought the domain. On the map drawn from an aerial photograph of 1956 (Fig. 3) we observed that the irrigated network was dense, with four levels of canals along the Rio Choapa and two levels in the Rio Manque valley. This irrigation system was presumably very ancient as certain canals date back to the

Table 1
Chillepin's population during the 1952–1998 (source INE and EDA 1998)

	1952	1960	1970	1982	1992	1998
Individuals	973	967	1004	1042	1124	1150
Families	150	169	182	242	297	302

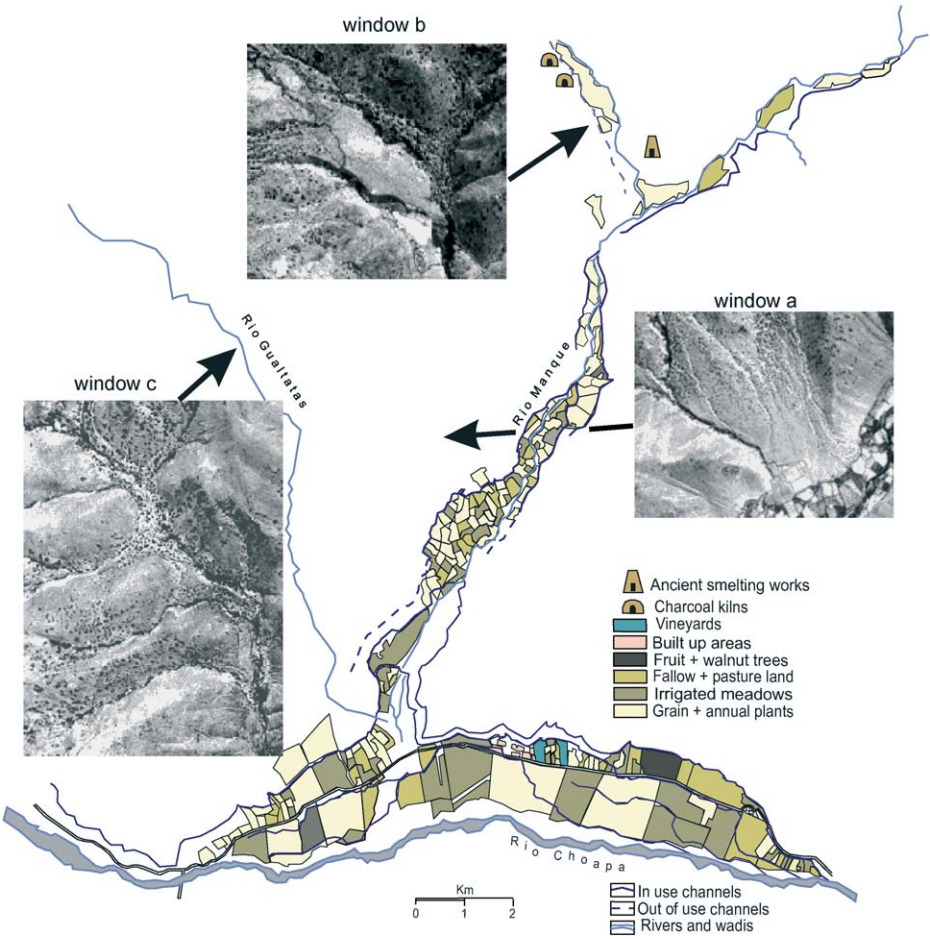

Fig. 3. The Chillepin fundo in 1956 from aerial photo interpretation.

Inca influence, in the 16th century during the pre-colonial period (Livenais and Santander, 1998). Along the Rio Choapa, the irrigated zone was divided into large lots of wheat, alfalfa and pasture for cattle breeding which were the main resources in the region (Table 3) most of which was shipped by rail to Santiago. Grain

Table 2
Individuals in the Salamanca town and the Chillepin district in the 1952s, 1970s and 1992s (source INE)

	1952	1970	1992
Chillepín district	973	1004	1124
All rural districts	12 258	12 533	12 950
Salamanca town	2858	5230	9052
Salamanca commune	16 089	18 767	23 126

Table 3
Agro-production of the Salamanca commune during the 1964–1997 (source INE)

	1964 (*Fundo*)	1975 (*Asentamientos*)	1997 (family farming)
Cultivated areas (ha)			
Grains	4433	3780	488
Vegetables	586	287	395
Pasture	2849	746	474
Fruit-trees	264	777	553
Vineyards	16	223	1189
Others	107	561	337
Total	8255	2594	2247
Livestock (heads)			
Cattle	17 439	17 092	10 274
Sheep	10 446	8622	2788
Pigs	4388	1432	320
Goats	24 784	35 248	15 507
Horses	4821	4839	4038
Total	61 878	67 233	32 927

production in the Chillepin fundo has a long history and was even reported by Chouteau (1887). Of secondary importance were tobacco, apricot and walnut trees, a few vineyards, fallow fields and natural meadows. In the Rio Manque valley, the irrigated zone was completely different and divided into small plots grouped together (Fig. 3). These lands were borrowed by the *inquilinos* for building their house and growing grain and vegetable for their own needs.

On the aerial photograph of 1956 we observed that the Rio Manque valley lower slopes were bare of all vegetation and showed the outline of the plots used for rain farming (Fig. 3, window a). Upstream in the valley, there was a wheat field along an ancient canal and, around the remainders of ancient smelting works, the hills were bare with only a few isolated trees featured as black dots on the photo (Fig. 3, window b). On the other hand, in the Gualtatas valley (Fig. 3, window c) thick vegetation grew along the valley bottom, with trees on the slopes. If mining activities had ceased, in 1956 the wood extraction had not disappeared because of an increasing demand. This demand did not come from Chillepin or any other rural district whose population remained stable between 1952 and 1970, but from

Salamanca, an important urban centre at approximately 40 km from Chillepin. Here were the small industries, the grape distilleries and the tobacco dryers, which all ran with fuel-wood, and a population of potential wood-consumers that grew at a rate of 1.83 during the 1952–1970 (Table 2). The enquiry report (EPD 2000) confirmed that tree cutting was intense in the Rio Manque valley. Every week and all along the year a lorry load of charcoal was sold, i.e. about 750 kg, which corresponds to a dry wood output of 150 T/year. *Prosopis chilensis*, *Acacia caven* and *Kageneckia angustifolia* dense wood varieties were the most in demand. With an output of 24 T/year (EPD 2000), the fuel-wood was also a source of profit for the *fundo* and its manager who received from the lumbermen a fee per kg of wood cut on the estate. It has also been reported (EPD 2000) that there was a sawmill on the estate and all the poplars growing along the canal banks were, in this period, cut for local needs.

To sum up, on one hand there was an irrigated area organized as a big agricultural enterprise based on wheat production and cattle breeding and, on the other, a vast mountainous hinterland used for charcoal and fuel-wood production that remained an important source of profit for the *fundo*. In this hinterland a number of places near valley bottoms were devoid of vegetation. Observations of nearby areas with dense sclerophyll shrub vegetation in similar topographic conditions (Alvarez et al., 2002) suggest that a severe loss of natural land cover has happened. This was particularly evident around ancient plots of rain farming and in the surroundings of old charcoal kilns and smelting works. In more remote valleys, such as the Gualtatas valley, deforestation was not reported and several oral histories converged in attesting to abundant *P. chilensis* and *K. angustifolia* in these sectors (EDP 2000).

Deforestation for mining activities which occurred before the studied period (Aschmann, 1990) could also have a strong impact on the land cover of 1956. In fact, it was only around 1940 that, in the Rio Manque upper valley, the lead mines, the ore smelting and the wood cutting of *Prosopis chilensis* to fire the smelting works closed down (EDP 2000). Although no quantified information is accessible, the beginning of the 20th century was presumably a period of intense wood cutting in the region for charcoal production, as confirmed by the observation of two huge charcoal kilns from this period (Fig. 3, window b) and an enquiry report (EDP 2000) about a tree felling machine that have been in use as late as 1928 in the adjoining San Agustin *fundo*.

3.2. 1967–1975, the social upheavals

In 1965 the decision was made to expropriate all the *fundos* of the Salamanca commune with compensation to the owners. The CORA (Corporacion de la Reforma Agraria), a committee of the Ministry of Agriculture, was in charge of the expropriation and the organization of collective farming systems named *Asentamientos* (Echenique, 1972). In 1967 the expropriation of the Chillepin *fundo* was realized. Between 1967 and 1973, at the end of the Allende presidency, a collective organization was put in place under the CORA's supervision (CORA, 1968), in

which the peasants took control of their holdings through loans contracted with the State and the traders of Salamanca (Astorga and Contreras, 1967). This period, known as *Asentamientos*, remains in the local memory as years of hard living conditions.

During this period the peasants moved from the Rio Manque valley towards the irrigated areas formerly occupied by the *fundo* and set about growing essential food stuffs such as beans, maize and potatoes. As no aerial photo was available on this period, there is little information on the land use and the size of the plots. Nevertheless many abandoned irrigated plots were then turned into pasture as cattle and goat breeding was still important (Table 3). In the hinterland, under the CORAs care, the charcoal production was pushed up to 57.6 T/year and deforestation affected more remote areas such as the Gualtatas valley that were not touched till this period (EDP 2000). If one adds the village firewood needs, estimated of 20 T/year on the basis of the current figures, the annual yield would, for the period, equal 308 T/year of wood.

The Counter Reform was created in 1974 in the first years of the Military Regime and meant a return to small private properties. The Chillepin's Allotment Project, set up in 1975 by the same CORA committee (CORA, 1975), envisioned (i) a regrouping of the population in a village, with a small housing plot to every family, (ii) irrigated plots for cultivation attributed to a portion of the population and (iii) the whole hinterland attributed to the whole population as a commune land. Effectively, all the 150 families formerly attached to the *fundo* were offered a plot to live on, of approximately 0.5 ha. But the allotment of cultivation plots with the related 'water rights' for irrigation (SAG, 1980) only concerned 69 out of 150 candidates. The size of the lots varied from 6 to 28 ha, according to the different soil values. The prices paid by the peasants for the lots and the dates of the instalments over a 25 years period were included in title deeds and registered in the town of Illapel (Registro de Popriedades de Bienes Raíces de Illapel, 1976). The peasants who received a cultivation plot were under the obligation to work their land in person and under the interdiction of dividing, transferring, leasing out or sharecropping without CORA's authorization. These rules were probably at the origin of the stability of the land tenure observed during 25 years later. The third point of the project related to the hinterland failed for financial reasons: the acquisition was refused by the community of the Chillepin peasants and these lands were thus sold in 1976 to a private buyer, and then resold in 1980 to the Anaconda SA mining company. The consequence of this decision was to separate the valley from its hinterland and to do away with extensive breeding activities in Chillepin.

After the land attributions of 1975, Chillepin became two large entities: an area of family farming for 872 ha and a vast privately owned dryland for 19 145 ha. Nevertheless, one can see (Table 4) that 268 ha of the irrigated land were not attributed and kept as State-owned land by the CORA and 222 ha of formerly irrigated land in the Rio Manque valley were attributed to the vast dryland estate. We therefore see that 490 ha of irrigated land, which is 35% of the initial irrigated zone, were left to no purpose after the land attributions and brought about a severe reduction of the irrigation network.

Table 4
Changes in irrigated and non-irrigated areas after the Land Attribution Project of 1975 (Proyecto de parcelación de Chillepin, 1975)

	Before 1967 (ha)	After 1976 (ha)	Variation (ha)
Family farming (69 lots)	0	795	
Village (150 lots)	0	77	
Commune land	0	15	
State-owned land	0	268	
Total irrigated land	1377	1155	−222
Non-irrigated land	18 923	19 145	+222

Table 5
Changes in area and tenure of the cultivated lots between 1975 and 1998 (source EDA 1998)

	Cultivated plot owner				Cultivated plot area			
	Family head	Wife	Direct descendant	Other buyer	Unchanged	Increased	Decreased	Divided
1975	69	0	0	0	69	0	0	0
1998	42	12	3	12	45	2	17	5

Table 6
Number of cultivated lots with 0, 1, 2, 3 or more sons of the family head working alongside their father or mother in 1998 (source EDA 1998)

	Number of sons working on the family lot in 1998					Total lots
	0	1	2	3	4	
Lots owned by the family head	7	21	9	2	2	41
Lots owned by the family head's wife	0	2	3	2	1	8
Total	7	23	12	4	3	49

3.3. 1975–1999, 25 years of family farming

In 1998, 57 cultivated plots out of the 69 created in 1975 still belong to the same families (Table 5) and, although the number of families had doubled in a population that has slightly increased between 1975 and nowadays, the proportion of families in the agricultural sector hardly changed: 46% in 1975 and 49% in 1998 (EDA 1998). The rural sector is still mostly occupied by the same family heads or their wife and the average number of sons working in the family estate alongside their father is 1.3 and alongside their mother is 2.25 (Table 6). On the whole, the rural sector of Chillepin shows a high retention rate of its population. More than daughters, many of the sons stay in Chillepin, eventually in their parent's house (Table 7). These 25

Table 7
Average number of sons and daughters of the family heads or his wife living in Chillepin in 1998 (source EDA 1998)

Estate owner	Family head		Wife of the family head	
Descendants	Sons	Daughters	Sons	Daughters
Average number of descendants	2.6	2.5	2.6	2.5
Living out of Chillepin	0.7	2.1	0.2	1.7
Living in Chillepin	1.9	1.1	2.4	0.8
Living in their parent's house	1	0.3	1.4	0.1

years were therefore a period during which the land tenure and the social structure created in 1975 remained quite unchanged (Livenais et al., 2000).

After 1967, when the peasants were refused access to the private hinterland, the pluvial agriculture disappeared and ceased definitively in 1975. The irrigation system in the Rio Manque valley, not cared for since 1967, rapidly collapsed, except for the downstream right bank canal which was reopened by diverting a tributary. On the map drawn from an aerial photograph of 1977, the size of the irrigated fields shrank considerably in comparison with 1956 and new plots of vineyards and orchards appeared. However, the definitive pattern of the family estates was not yet discernible as a number of fields were still uncultivated in 1977 and kept their *fundo* period outlines. Along the slopes where pluvial agriculture existed in 1956, a shrubby vegetation is observed in 1977 (Fig. 4, window a). In place of wheat fields afterwards used as pasture for sheep and cattle (Fig. 4, window b) one also detects newly grown bushy vegetation whereas, in the Gualtatas valley (Fig. 4 window c) tree density has quite notably shrunk since 1956.

Small vineyards have always existed in the Choapa valley. However, the family farming is the beginning of the grape growing for *pisco*, a typical Chilean brandy. The setting up at Salamanca of two industrial distilleries, 'Capel' in 1985 and 'Control' in 1990, was the starting point of intensive grape production. The number of Chillepin grape growers rose from 16 in 1990 to 29 in 1992 and 51 in 1996 (INE). This specialization brought financial security as the sale of the harvest was guaranteed and payable in monthly instalments over the year. Nevertheless, as production methods and prices were controlled by the distillers and not in total accordance with the individualism of the peasants (EDA 1998), most of them preferred to keep working at vine, fruit trees, walnut trees and alfalfa in mixed farming rather than vine monoculture, in spite of the trading difficulties they met. They also reduced the number of livestock of whatever type all through this period (Table 3).

In the non-irrigated territory, from the 1975–1980, cattle breeding was reintroduced by a private land-owner and charcoal production was prohibited. Nevertheless, illegal tree cutting still existed, estimated to reach 20 T/year (EDP 2000). From the 1980–1994, the Anaconda Mining Company acquired the whole territory and charcoal production was resumed, this time for the personal benefit of the local manager, to the weakly rate of 250 kg of acacia charcoal, which is

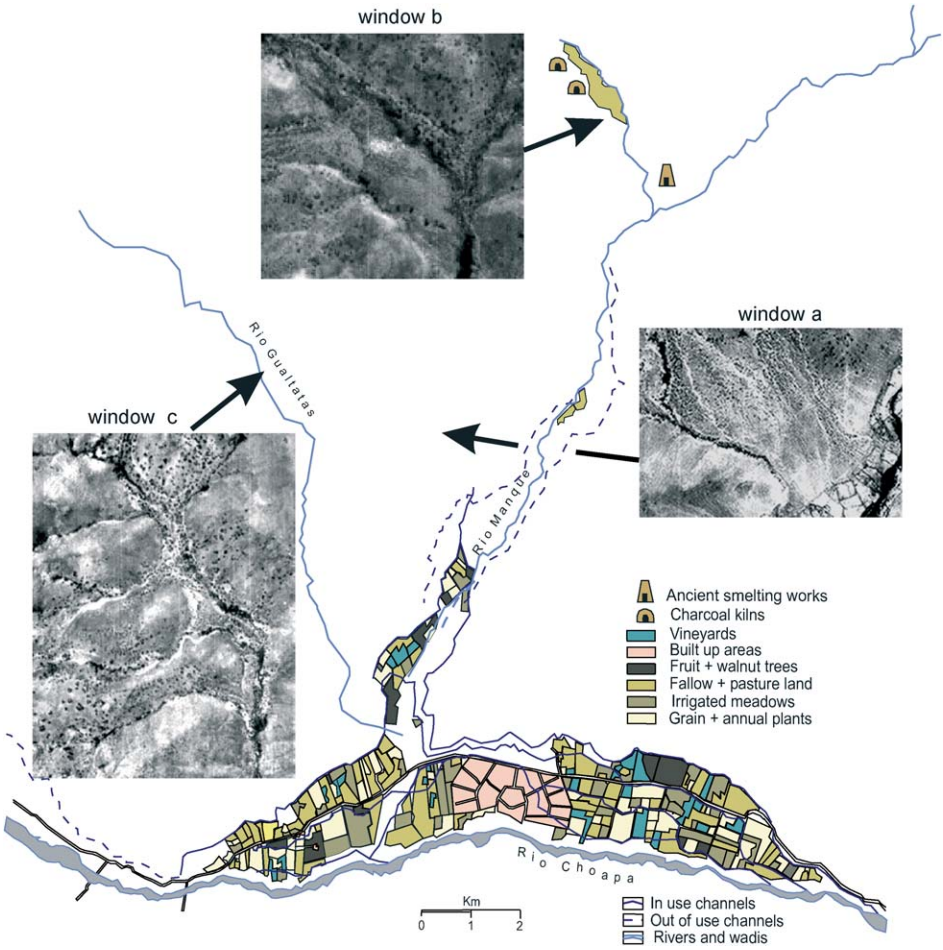

Fig. 4. The Chillepin district in 1977 from aerial photo interpretation.

approximately 50 T/year of dry wood (EDP 2000). About 10 lumbermen also came to extract the fuel-wood necessary for Chillepin's domestic consumption, at the rate of 450 kg per week, i.e. 18 T/year (EDP 2000). Over the 1980–1994 period, the exportation of wood from the district therefore amounted to 68 T/year. From the 1994s to present day, the international mining company 'Los Pelambres' took control of all this private territory (Moguillansky, 1998). Access was restricted and charcoal production came to an end. In 1996 the Rio Manque valley was closed and the goat herds were first evacuated towards the Gualtatas valley and then, further South, to the cordillera. These changes brought about a severe limitation of firewood extraction. In 1994 there were five lumbermen for about 755 kg of firewood per week, i.e. 30.2 T/year. In 1996 they were only three, cutting illegally about 18.2 T/year (Table 8). These figures are in accordance with the trend in family fuel

Table 8
Fuel-wood and charcoal extraction from the Chillepin district under different land-owners during the 1975–2000 period, in tons of dry wood (source EDP 2000)

Period	Owner	Total	Annual
1976–1980	Private owner		
Charcoal		0 T	0 T
Lumber		72 T	18 T
1980–1994	Anaconda SA Mining Co.		
Charcoal		700 T	50 T
Lumber		252 T	18 T
1994–1996	Pelambres Internat. Mining Co.		
Charcoal		0 T	0 T
Lumber		60.4 T	30.2 T
1996–2000	Pelambres Internat. Mining Co.		
Charcoal		0 T	0 T
Lumber		65.6 T	16.4 T
1976–2000	Total period	1150 T	

Table 9
Family fuel consumption of 100 households from Chillepin (source ECE 2000)

Energy source	Domestic use		
	Cooking	Boiling water	Heating
Wood	0	22	45
Charcoal	0	0	5
Gas	35	52	6
Kerosene	0	0	11
Wood + other	4	2	5
Charcoal + other	0	0	3
Gas + other	61	19	1
Kerosene + other	0	0	2
No response	0	5	22
	100	100	100

consumption: fuel-wood was then largely offset by the use of gas (Table 9) whilst population remained almost the same during the 1952–1998.

3.4. 1999, Chillepin's present-day situation

Since 1977, the irrigation network has substantially shrunk. The highest upstream canal of the Rio Choapa has been cut in the middle. The end of the canal immediately below has collapsed. With the exception of some fallow land, all the irrigated plots are now intensely cultivated. Vineyards and orchards—essentially peach and apricots—cover more than $\frac{2}{3}$ of the area. The built up area has also expanded, both in the village and in the cultivated plots.

In the non-irrigated sector, a revival of the vegetation can be seen along the lower slopes (Fig. 5, window a) which were bare of vegetation and used for rain farming 30 years ago. Trees—mainly *Lithrea caustica*—now grow 3–6 m apart, which corresponds to a phytovolume of 5000 m^3/ha. Where a wheat field once existed in 1956, then becoming pasture land in 1977 (Fig. 5, window b), now grow shrubs of 'Espino' (*Acacia caven*) and 'Huingan' (*Schinus polygamous*) with a phytovolume of 3600 m^3/ha. In the same sector, one can observe scrubby vegetation mostly of *Colliguaja odorifera* and *Treboa qinquinervia* on hillsides that, in 1956, were bare. Finally, in the Gualtatas valley (Fig. 5, window c) one can see some revival of the trees which still have not reached their aspect of the 1956s.

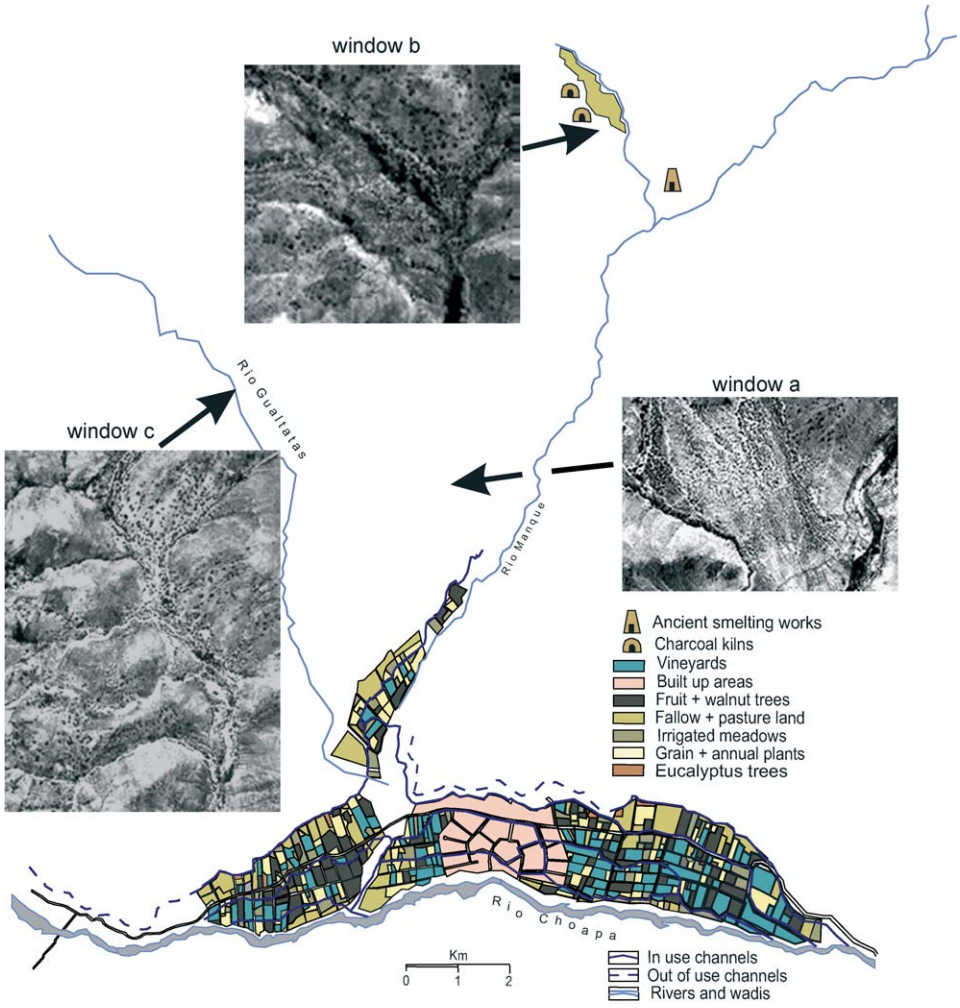

Fig. 5. The Chillepin district in 1999 from aerial photo interpretation.

4. Discussion

The traditional irrigation system, which works through gravity and canals, is still in use but it has been continuously shortened from 1956 and 1999 (Fig. 6). The 1977 reduction coincides with the 1975s land repartition that abandoned 222 ha of irrigated lands in the Rio Manque valley. The reduction of the 1999s concerns a portion of the two upper Chillepin canals and corresponds to lands that were put in reserve by the CORA and have never been allocated since 1975, thus never been maintained.

As one follows the vegetation's change from 1956 till 1999 in the sector of window a in the maps, one can deduce that 30 years are necessary for the rebirth of tree vegetation in a rain farming sector cultivated up to 1967 and then abandoned (Fig. 7a). But the newly grown tree cover is much thinner and poor in species than the sclerophyll shrub vegetation presently observed as remainders in nearby valleys (Alvarez et al., 2002) and which is supposed to have existed before the rain farming was installed (Mooney et al., 1972). Past rain farming activities are thus the cause of irreversible modifications of the natural land cover in these regions.

As one follows the vegetation's evolution of window b in the maps, beginning with a wheat field in 1956, left fallow shortly afterwards and then fenced pastureland for sheep and cattle during approximately 35 years till 1999, one notices the growth of shrubby vegetation mainly of *A. caven* and *S. polygamous* (Fig. 7b). This is an example of the important role of ruminant livestock in disseminating ingested seeds of *A. caven* and *S. polygamous* (Torres et al., 1987).

In the sectors such as window c in the maps, submitted to deforestation only after 1956, things developed with a minimal of vegetation in 1977 (Fig. 7c) and a partial recovering in 1999 of tree species such as *Quillaja saponaria* and *Lithrea caustica* which are able to re-growth from the stump.

From these examples we observe that three different types of present-day ligneous vegetation are in fact the result of three different human disturbances such as rain farming, extensive livestock breeding and lumbering which occurred some 30 or 35 years ago.

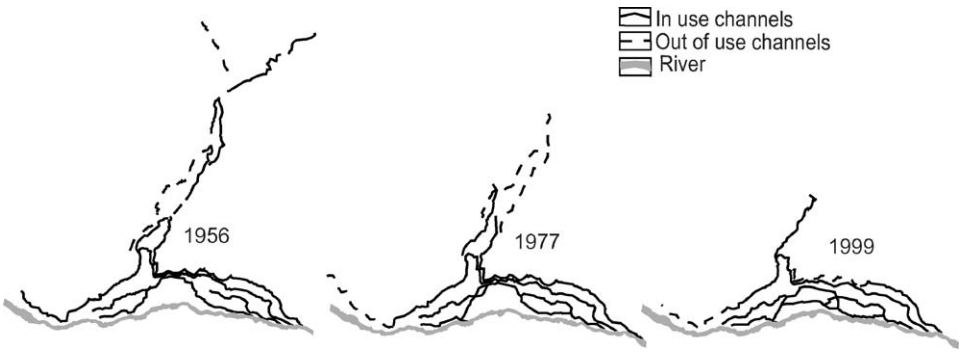

Fig. 6. Evolution of the irrigation network during the 1956–1999 period.

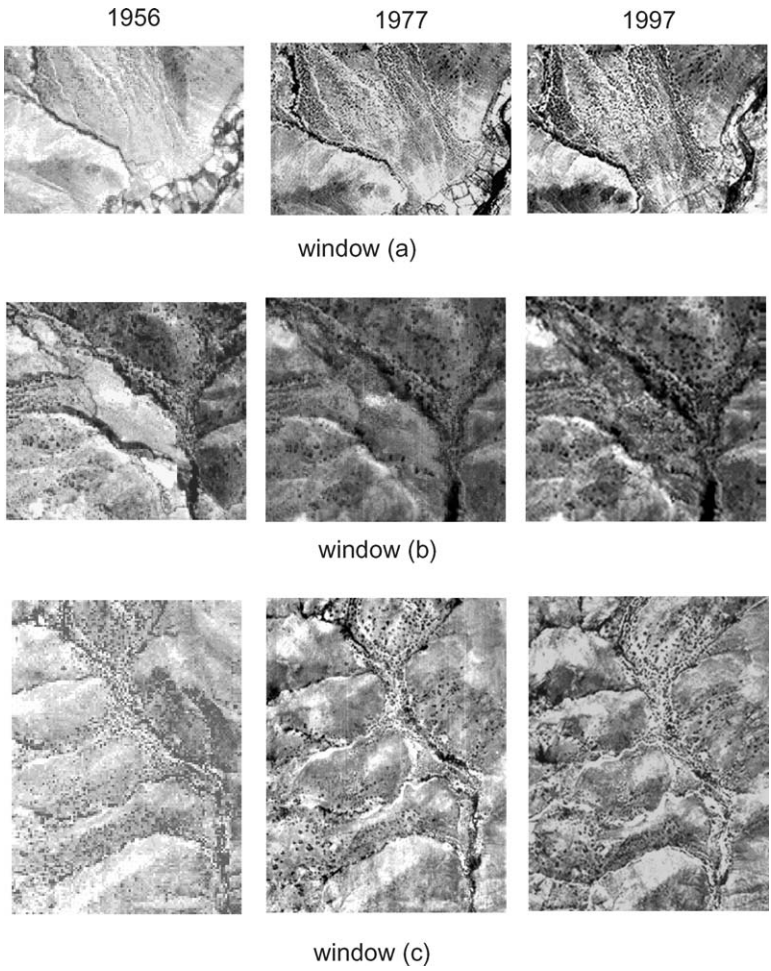

Fig. 7. Evolution of three non-irrigated zones of Chillepin during the 1956–1999 period.

In the Chillepin territory, wood extraction has been very important during the last 50 years, adding up to 175 T/year during the last moments of the *fundo*, and reaching a 308 T/year climax between 1967 and 1975 during the period of social upheaval known as *Asentamientos*. It is also likely that charcoal prices were high in this period, due to the heavy demand after the law prohibiting exploitation of acacia trees was passed. After 1975 the quantities decreased to 20 T/year, then again they grew to 68 T/year in 1980 and then to 30.2 T/year in 1994. It is only in 1996 when the mining company set up an effective watch of the non-irrigated territory that wood extraction fell to 18.2 T/year (Fig. 8).

The quantity of extracted wood for the whole period reaches 5275 T. Considering the biomass of the native sclerophyll shrub cover to be between 2 and 5 T/ha (Prado et al., 1987; Aguirre and Infante, 1988; Santander, 1993), the deforestation is

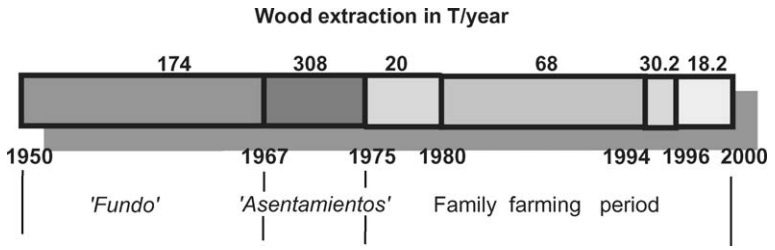

Fig. 8. Estimated wood extraction from the Chillepin district during the last 50 years. The climax extraction occurred during the 1967–1975 period.

equivalent to the destruction of 1000–2700 ha of native shrubs. This extensive destruction explains the woodland's sluggish recovery and also that the hard wood species such as *Prosopis chilensis* have disappeared, now replaced by the 'matorral' a secondary scrubby vegetation mostly of *Colliguaja odorifera*.

5. Conclusions

The first two periods identified as the '*fundo*' and the '*asentamientos*' were notable for the important hinterland's deforestation for charcoal production, a damaging activity undertaken for immediate benefits and little thought for future consequences. The setting up of the family farming in 1975 after two successive social upheavals carried along to the scaling down of the irrigated area and the intensification of the irrigated farming. In spite of a specialization in grape growing for *pisco*, the peasants have kept up the traditional mixed farming using few chemicals and little mechanical help. Through these traditional practices they have ensured sufficient incomes and have preserved their estate. All this brought about stability of the land tenure, high retention rate of the rural population and slight increase of the whole population of Chillepin during the 1975–1999 period. This situation is quite different from most rural districts in the 4th Region of Chile that are nowadays an important source of emigration (D'Andrea and Hamelin, 2000).

The mountainous hinterland, separated from the irrigated land, became a vast privately owned estate in which the vegetation slowly recovered. This happened firstly by the phasing out of all pluvial agriculture when the peasants had their own irrigated farm, secondly by the discontinuance of commercial production of charcoal, thirdly by the use of gas that have reduced the domestic fuel-wood consumption and, fourthly, by the recent closing off and control of the rangeland.

Finally, during the last 50 years human activities in the Chillepin district have caused radical changes to the environment. These impacts have not been brought about by any demographic pressure or dramatic drought, for, if the number of families has doubled, the population has slightly increased (Table 1) and rainfall has not changed on the whole since 1959 (Fig. 2). They were brought by social changes. Between the three social systems that have influenced man's interventions on the

area, the family farming shows, till today, positive environmental effects and more stability in terms of population and land tenure.

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