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RESEACH PAPER

Systematic transitions in land use and land cover in a pre-Andean sub-watershed with high human intervention in the Araucania Region, Chile

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Abstract

P. Saavedra Briones, and A. Sepúlveda-Varas. 2016. Systematic transitions in land use and land cover in a pre-Andean subwatershed with high human intervention in the Araucania Region, Chile. Cien. Inv. Agr. 43(3):396-407. Historical studies of land use changes help us to understand the current configuration of the landscape and identify the environmental and social impacts that are associated with these transformations. Several authors describe the transitions as a process of change that transforms the landscape system; for systematic transitions, these transitions are driven by stable and gradual processes. The objective of this study is to determine the trajectory and magnitude of land use and land cover (LULC) change for the 1994-2007 period in a pre-Andean sub-watershed with intensive human use in the central-southern zone of Chile and to analyze the most significant systematic transitions between land cover types. The results confirmed the reduction in the areas of agriculture and livestock and the increase of exotic plantations use on surfaces intended for agricultural use. The significant transitions were the conversion at a rate gain of 384 ha/year of "Farmlands" to "Exotic plantations", the abandonment at a loss rate of 119 ha/year of "Perennial grasslands" to "Native vegetation", the degradation at a loss rate of 93 ha/year of "Native vegetation" to "Perennial grassland", and the revegetation at a rate gain of 60 ha/year of "Exotic plantations" to "Native vegetation". The new patterns and trends in the use and intensity of land use reaffirmed the need for studies on the updated status of natural resources, particularly soil resources. This work, we believe, is a technical tool to support the sustainable management of a territory and the decision-making processes on land use.

Key words: Chile, land cover change, land use planning, LULC, systematic transitions.

Introduction

Evaluating the effects of land use and land cover (LULC) changes on terrestrial ecosystems depend largely on the knowledge of past practices (NRC, 2001). Historical studies of LULC changes help researchers understand the current configuration of the landscape and identify the environmental and social impacts that are associated with these transformations (Andersen *et al.*, 1996; Pan *et al.*, 1999). Moreover, the modeling of scenarios

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can be used to link trends in vegetation cover changes with the underlying processes that are responsible for the changes in land cover. This connection helps researchers understand the mechanisms involved, generates predictions for future rates of change, identifies vulnerable sites, and contributes to the design of policies that can adequately respond to LULC changes (Braimoh, 2006; Henríquez *et al*., 2006; Pineda *et al*., 2009; Camacho *et al*., 2010). The regional analysis of land cover changes in heterogeneous landscapes can be masked by spatial variations caused by both bioclimatic and socioeconomic factors (Martínez-Fernández *et al*., 2015). According to Pontius *et al*. (2004), an appropriate methodology to analyze changes in land use is to obtain maps at two different times, examine the changes with a transition matrix to identify the most important transitions, and then investigate the processes that generate the transitions between land cover types. Often, researchers analyze this transition matrix at a very general level (e.g., CONAF-CONAMA-BIRF, 1999; Aguayo *et al*., 2009; CONAF-CONAMA, 2009; CONAF, 2011) and draw conclusions about the dynamics of LULC change based only on the net change in the class totals between the years (Mertens and Lambin, 2000; Braimoh, 2006). However, the net change can dramatically underestimate the total change in the landscape (Mertens and Lambin, 2000). It is possible that the change occurs in such a manner that a given category changes its location between sampling times, but its magnitude stays the same (Pontius *et al*., 2004).

A common limitation of LULC change studies is that they consider change as one simple and irreversible conversion of one land cover type to another (Mertens and Lambin, 2000). Human societies coevolve with their surroundings, and the primarily nonlinear changes in LULC are related to social, physical, and biological changes at different organizational levels and occur through a multitude of transitions and trajectories between land covers that generate new complex patterns of land use (Braimoh, 2006; Carmona *et al*., 2010; Carmona and Nahuelhual, 2012). A transition is a process of change that transforms the landscape system (Carmona and Nahuelhual, 2012), and transitions between land cover types are classified as random or systematic (Pontius *et al*., 2004; Braimoh, 2006). Random transitions are those that are influenced by involuntary processes or a single change; these transitions are characterized by abrupt changes and are often associated with the ability of an ecosystem to recover (Lambin *et al*., 2003; Pineda *et al*., 2009). The causes of such transitions tend to be factors that act unexpectedly, such as spontaneous population migration, internal land conflicts, and economic crises, among others (Lambin *et al*., 2003). Systematic transitions are driven by stable and gradual processes; these transitions are caused are permanent forces, such as natural population increases, the expansion of markets, and governmental changes in terms of the institutions that control access to resources (Lambin *et al*., 2003; Pineda *et al*., 2009; Carmona and Nahuelhual, 2012). Systematic transitions are identified when the difference between the observed rate and the expected value (based on gains or losses that are expected to randomly occur) are significantly different from zero (Braimoh, 2006; Pineda *et al*., 2009).

In this regard, human activities are the primary triggers of transformations in the landscape and land use changes associated with the processes of urban, industrial and productive growth (Yuan *et al*., 2005; Mas *et al*., 2009). In Chile, Nahuelhual *et al*. (2012) noted that the areas more vulnerable to future change in the southern regions of the country would be those located on soils that are marginal for agriculture (e.g., areas in the Andes and Coastal Ranges). These areas also concentrate high levels of rural poverty; therefore, recognizing these characteristics can be critical for designing conservation policies suited for each region (Martínez-Fernández *et al*., 2015). In this sense, the objective of this study is to determine the trajectory and magnitude of LULC change for the 1994-2007 period in a pre-Andean sub-watershed with intensive human use in the central-southern zone of Chile and to analyze the most significant systematic transitions between land cover types.

Materials and methods

Study area

The pre-Andean sub-watershed of the Quepe River is located between the latitudes 38°40'S and 39°00'S and the longitudes 71°45'W and 73°00'W in the Araucaria Region of Chile (Figure 1). The sub-watershed covers an area of 1.604 km^2 in the regional Intermediate Depression; soils are mostly grouped in the Andisol order, which are derived from volcanic ash, with a high field capacity (40 to 60% at 33 kpa), high total porosity (60 to 80%) and good internal drainage (CIREN, 2002). It is an exorheic sub-watershed with a pluvial regime and a rainy warm temperate climate with Mediterranean influence (Cfsb) and a reduced summer period of two months, according to the Köppen classification. The mean annual temperature is 12 °C, the mean relative humidity is 80%, and the mean annual rainfall is 1.324 mm (Di Cqaastri and Hajek, 1976; PLADECO, 2010a; PLADECO, 2010b). Heading east to west, the following three plant formations were observed: 1) Deciduous Forest of the Andes with Araucaria, 2) Mixed Deciduous Forest of the Andes and 3) South Deciduous Forest. The dominant economic activities are services, agriculture and forestry and construction.

Temporal analysis of the components of change between 1994 and 2007

The cartographic delimitation of the sub-watershed was determined by the General Water Directorate (DGA, 2004). Land covers were obtained from the following cartographic databases: the "Survey and Evaluation of the Native Vegetation Resources of Chile" (CONAF-CONAMA-BIRF, 1999) and its update (CONAF, 2011). Vector cartographic coverages were built based on photo interpretation of aerial photographs (1994) and orthophotos (2007) that had been orthorectified and corrected. Land covers were reviewed and homologated for the Geocentric Reference System for the Americas (i.e., the Universal Transverse Mercator (UTM) projection, which was based on Wideband Global SATCOM (WGS) 84 data for extended zone 18 South). The data were processed using ARCGIS

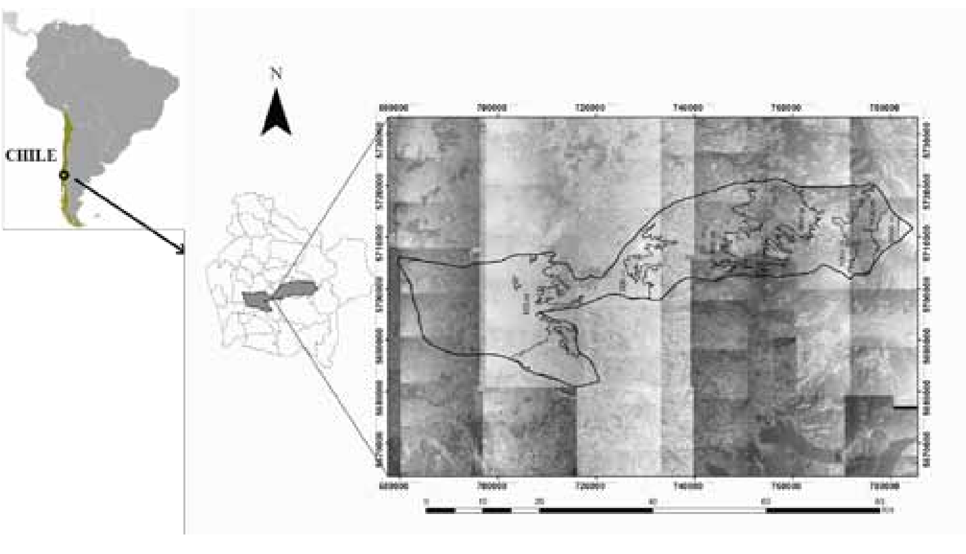

Figure 1. Study area in the Araucania Region, in the central-southern zone of Chile, at a sub-watershed of the Quepe River.

9.3.1 software package (ESRI, USA). Meanwhile, cover classes were built based on a simplification and aggregation of the "General Vegetation Classification System" developed for the project "Survey and Evaluation of the Native Vegetation Resources of Chile" (CONAF-CONAMA-BIRF, 1999). The classes were as follows: (1) Native vegetation, (2) Farmlands, (3) Exotic plantations, (4) Perennial grasslands, and (5) Other coverage. All classes were based on the Charter of Land Occupation Montpellier.

Maps from 1994 (time 1) and 2007 (time 2) were analyzed using a change matrix constructed according to the method proposed by Pontius *et al.* (2004) and systematized following Braimoh (2006). In our study, the rows indicate the proportions of the five categories of cover in 2007, whereas the columns correspond to the proportions of the five categories of cover in 1994. The notation C_{ij} ($i \neq j$) indicates the proportion of landscape that underwent a transition from category i to category j between 1994 and 2007. The components of the main diagonal, which are designated c_{jj}, indicate the proportion of cover of category j that remained stable.

Based on the information in the matrix, the gross losses (L_{ij}), gross gains (G_{ij}), total change (D_j), net change (C_j), and swap (S_j) between categories were calculated. The gross loss (Eq. 1) is the difference between the total time 1 column (c_{j+}) and persistence (c_{jj}). The gross gain (Eq. 2) is the difference between the total time 2 row (c_{+j}) and persistence (c_{jj}). The swap (Eq. 3) is defined as twice the minimum value of the gains or losses. The net change (Eq. 4) is the difference between gains and losses. The total change (Eq. 5) is considered the sum of the net change and swap or the sum of gains and losses (Pontius *et al.*, 2004; López and Plata, 2009).

$$L_{ij} = c_{j+} - c_{jj} \tag{1}$$

$$G_{ij} = c_{+j} - c_{jj} \tag{2}$$

$$S_j = 2 \times min\left(c_{j+} - c_{jj}, c_{+j} - c_{jj}\right) \tag{3}$$

$$C_j = (G_{ij} - L_{ij}) \tag{4}$$

$$D_j = C_j + S_j \tag{5}$$

Identification of key signals of change

To determine whether they were systematic or random in nature, the transitions between categories were analyzed according to the method proposed by Pontius *et al.* (2004), systemized by Braimoh (2006) and endorsed by López and Plata (2009), Pineda *et al.* (2009), and Carmona and Nahuelhual (2012). This method involves the construction of two systematic transition matrices based on the gains (Eq. 6) and losses (Eq. 7) that are expected to randomly occur.

$$g_{ij} = \left(c_{+j} - c_{jj}\right) \times \left(\frac{c_{i+}}{1-c_{j+}}\right),\ i \neq j \tag{6}$$

The difference (d_j) between the observed values in the change matrix (*Vo*) and the expected values (*Ve*) under a process of random gain or random loss was determined and extracted from the systematic transition matrix based on the expected gains and losses, respectively. For more details regarding obtaining both matrices, see Pontius *et al.* (2004).

$$l_{ij} = (c_{i+} - c_{ii}) \times \left(\frac{c_{+j}}{1-c_{+i}}\right),\ i \neq j \tag{7}$$

To provide conclusive evidence for a key signal of landscape transformation, class i must systematically win over class j, and class j must systematically lose to class i (Alo and Pontius, 2008).

Indices of persistence and rate of change

Additionally, the rates of change for each category were calculated using the formula proposed by the FAO (1996) and the indices of persistence proposed by Braimoh (2006). P corresponds to the annual percentage of change of a single category (Eq. 8), whereas S_1 and S_2 correspond to the surfaces at time t_1 and t_2, respectively. Any quotient greater than 1 in Eqs. (9), (10), and (11) indicates a high tendency of a category to transition to another category rather than persist. G_p corresponds to the index of gain-persistence, l_p is the index of lost-persistence, and n_p is the net-persistence index.

$$p=\left(\frac{100}{t_2\text{-}t_1}\right)\times ln\frac{S_2}{S_1} \quad (8)$$

$$g_p=\frac{G_{ij}}{c_{jj}} \quad (9)$$

$$l_p=\frac{L_{ij}}{c_{jj}} \quad (10)$$

$$n_p = g_p - l_p \quad (11)$$

Results and discussion

Components of change

Table 1 summarizes the values of the components of change analyzed for the sub-watershed. The category that had the highest gross loss was "Farmlands", with a 7.57% decrease of surface at the landscape level; this category also experienced the greatest net change (49% of the total change). The categories that experienced the highest gains corresponded to "Native vegetation" and "Exotic plantations" at 5.65 and 4.37%, respectively. The land cover types that had the greatest surface swap dynamics corresponded to "Native vegetation" at 7.83% and "Farmlands" at 5.18%. Although "Exotic plantations" exhibited low swap, they constituted the category with the greatest annual change at 5.22% and the highest rate of gains-losses at 5.00% during the period of 1994-2007. This category also had the greatest value for the net positive change (67% of the total change in the category; i.e., net change as part of the total change).

The swap represents changes in location between land covers, whereas the net change is associated with measurable irreversible change in the surface of one land cover to another (Braimoh, 2006; Alo and Pontius, 2008); having these two components of change allows the actual spatial dynamics of LULC change in the study area to be determined (Pontius *et al*., 2004). In this manner, it is possible to determine the total change in LULC between 1994 and 2007 and highlight the land cover types that exhibited the greatest variation (López and Plata, 2009). Thus, "Native vegetation", "Farmlands", and "Exotic plantations" were the land cover types that underwent the greatest spatial changes in the study area.

Indices of persistence

In the diagonal of Table 2, the percentages of persistence of each category during the period of 1994-2007 are listed. The total persistence of the study area reached 85.8%, whereas the percentage of the surface that underwent a change in land cover was 14.2%. "Farmlands" exhibited the highest persistence, maintaining a stable 56% of surface relative to 1994, followed by "Native vegetation" with 20% stability for the same period. The remaining categories exhibited a persistence

Table 1. Components of change (%) of land cover of the study area during the period of 1994-2007.

	Loss	Gain	Total change	Swap	Rate of gains-losses	Net change
Native vegetation	3.91	5.65	9.57	7.83	0.54	1.74
Farmlands	7.57	2.59	10.17	5.18	-0.63	-4.98
Exotic plantations	0.87	4.37	5.24	1.74	5.22	3.5
Perennial grassland	1.47	1.11	2.58	2.23	-0.46	-0.36
Other coverage	0.37	0.47	0.84	0.75	0.26	0.1

of less than 5% (based on the diagonal of persistence); this result highlights the need to analyze off-diagonal entries to avoid underestimating or overestimating changes. A change of 14.2% in the study area landscape represents a higher than normal change, considering that persistence often dominates the landscape in the majority of cases and is greater than 90% (Pontius *et al*., 2004).

Table 3 presents the results regarding the persistence of each category. The columns of g_p and l_p indicate that the categories exhibited a low tendency to transition from loss or gain to another category, with the exception of "Exotic plantations", which had the highest value of g_p (1.60). This result indicates a high tendency for this land cover type to gain surface instead of remaining stable. A g_p value of 1.6 means that the surface over which the category increased during the 1994-2007 period is 160% greater than the surface over which this land cover type remained stable. Additionally, the n_p value for "Exotic plantations" was greater than those of the other covers with a value of 1.28; this category tended to gain rather than lose as a function of its persistence. Thus, the net gains of "Exotic plantations" corresponded to 128% of the surface of its respective persistence.

Previous results confirm the advance of exotic forest surface in the study area at the expense of agricultural land, which is the same as the regional trend observed in the Araucanía (CONAF-CONAMA, 2009). This situation is primarily explained by the incentives granted by the State for the cultivation of exotic species and by the comparative advantages of the profitability of one item over another, e.g., livestock or agriculture (Aguayo *et al*., 2009; Carmona and Nahuelhual, 2012). Thus, "Exotic plantations" obtained greater gains than the "Farmlands" category, as indicated in Table 2. "Farmlands" experienced the greatest loss and total change of all the categories and had the lowest tendency to exhibit a transition of surface loss or gain to another category (Table 3). In this regard, López and Plata (2009) proposed that the enormous magnitude of persistence, compared with changes, could lead to erroneous conclusions about the dynamics of the territory. Thus, it becomes interesting to analyze the data outside the main diagonal because they help identify key and systematic patterns of change separate from any persistence level and land cover size (Pontius *et al*., 2004; Braimoh, 2006; Manandhar *et al*., 2010; Gutiérrez and Grau, 2014).

Detection of key signals of change

Table 4 presents the transitions based on the most significant gains between land covers. The most significant (positive) difference between the observed and expected value based on a process of random gains correspond to the transition from "Perennial grasslands" to "Native vegetation" at 0.51%. Because the difference between *Vo* and *Ve* is far from zero, this transition qualifies as systematic; "Perennial grasslands" were replaced by "Native vegetation" 1.14 times faster than expected from a random process of gains for the latter category. Similarly, "Perennial grasslands" exhibited a 0.47% higher gain than "Native vegetation" compared with that expected for a process of random gain for "Perennial grasslands".

The transition from "Native vegetation" to "Farmlands" also qualified as a systematic transition; the difference of 0.30% indicates that the category of "Native vegetation" was systematically replaced to gain "Farmlands." At the same time, in the transition of "Farmlands" to "Exotic plantations", the latter category gained an additional 0.22% compared with what was expected from a random process. Also notable is the systematic transition of "Exotic plantations" to "Native vegetation"; the "Native vegetation" replaced plantations, gaining an additional 0.22% of surface at a rate 0.74 times faster than that expected from a process of random gain of native vegetation relative to plantations. The negative differences between *Vo* and *Ve* also indicate systematic transitions

Table 2. Matrix of cover changes in the Quepe River sub-watershed. Each row corresponds to the total percentage of cover in 1994, and each column corresponds to the total percentage of cover in 2007.

		Year 2007						
		Native vegetation	Farmlands	Exotic plantations	Perennial grassland	Other coverage	Total 1994	Gross loss
Year 1994	Native vegetation	19.91	2.00	1.04	0.75	0.12	23.82	3.91
	Farmlands	4.00	56.2	3.11	0.15	0.32	63.78	7.57
	Exotic plantations	0.49	0.19	2.74	0.18	0.01	3.61	0.87
	Perennial grassland	0.96	0.28	0.21	4.61	0.02	6.08	1.47
	Other coverage	0.21	0.12	0.01	0.03	2.34	2.71	0.37
	Total 2007	25.56	58.79	7.11	5.73	2.81	100	
	Gross gain	5.65	2.59	4.37	1.11	0.47		

Table 3. Indices of gain-persistence (g_p), loss-persistence (l_p) and net-persistence (n_p) change of each cover for the period of 1994-2007.

	g_p	l_p	n_p
Native vegetation	0.28	0.2	0.09
Farmlands	0.05	0.13	-0.09
Exotic plantations	1.6	0.32	1.28
Perennial grassland	0.24	0.32	-0.08
Other coverage	0.2	0.16	0.04

Table 4. Primary systematic transitions based on gains between categories for the period of 1994-2007.

Transition	Vo	Ve	Vo – Ve	*Vo-Ve/Ve*	Interpretation
Native vegetation 1994 to Farmlands 2007	2	1.7	0.3	0.17	When farmlands expand, they replace the Native vegetation
Farmlands 1994 to native vegetation 2007	4	4.73	-0.73	-0.16	When the native vegetation expands, they do not replace farmlands
Native vegetation 1994 to exotic plantations 2007	1.04	1.08	-0.04	-0.03	When exotic plantations expand, they do not replace the native vegetation
Farmlands 1994 to exotic plantations 2007	3.11	2.89	0.22	0.07	When exotic plantations expand, they replace farmlands
Perennial grassland 1994 to farmlands 2007	0.28	0.44	-0.15	-0.35	When farmlands expand, they do not replace perennial grasslands
Perennial grassland 1994 to native vegetation 2007	0.96	0.45	0.51	1.14	When the native vegetation expands, they replace perennial grasslands
Native vegetation 1994 to Perennial grasslands 2007	0.75	0.28	0.47	1.66	When perennial grasslands expand, they replace the native vegetation
Exotic plantations 1994 to Native vegetation 2007	0.49	0.27	0.22	0.74	When the native vegetation expands, they replace exotic plantations

between categories. Thus, for the transition of “Farmlands” to “Native vegetation”, the negative difference indicates that the latter category avoided the systematic gain of “Farmlands”. The low value for the difference between “Native vegetation” and “Exotic plantations” indicated a random transition.

As observed from Table 5, the differences between *Vo* and *Ve* are greater than the differences based on gains. The highest difference corresponds to the transition from “Farmlands” to “Exotic plantations”, which indicates that “Farmlands” lost an additional 1.8% surface than expected under a random loss process at a rate 1.38

times faster than if the land had lost surface randomly. Transitions of "Native vegetation" to "Exotic plantations", "Perennial grassland" to "Native vegetation", "Native vegetation" to "Perennial grassland", and "Farmlands" to "Exotic plantations" exhibited positive differences, which confirmed the systematic character of surface transitions and involved the replacement of land cover that ceded land at an average loss rate that was 1.4 times faster than one would expect if the loss were random. Regarding transitions from "Native vegetation" to "Farmlands", "Farmlands" to "Native vegetation", and "Perennial grasslands" to "Farmlands", the negative differences denote that there was no replacement of the winning category for the losing category. Cultivated land did not replace "Native vegetation", and the tendency of cultivated land to avoid losing systematically to the latter category was high.

According to Alo and Pontius (2008), Braimoh (2006) and Manandhar *et al.* (2010), if category *i* systematically gains from category *j* and category *j* systematically loses to category *i*, the results indicate a process of systematic transition from category *i* to category *j*. Thus, by identifying systematic transitions based on gains and losses and verifying their simultaneous impact, key signals of LULC change in the study area are as follows (Figure 2): the conversion of 3.11% of "Farmlands" to "Exotic plantations" (a gain of 384 ha year^{1}), the abandonment of 0.96% of "Perennial grasslands" (a loss of 119 ha year^{1}) to "Native vegetation", the degradation of 0.75% of "Native vegetation" (a loss of 93 ha year^{1}) to "Perennial grasslands", and the revegetation of 0.49% of "Exotic plantations" to "Native vegetation" (a gain of 60 ha year^{1}).

Although the remaining transitions (Table 4 and 5) were also systematic, the lack of simultaneous incidences indicates that the results neither reveal the key signals of change in the landscape that this study seeks nor offers a clear vision regarding the covers that were subject to greater pressure (Stefanov *et al.*, 2001; Cheng and Yang, 2008). Farmlands had the most extensive land cover in the study area and one of the greatest magnitudes of change (Table 1); these areas

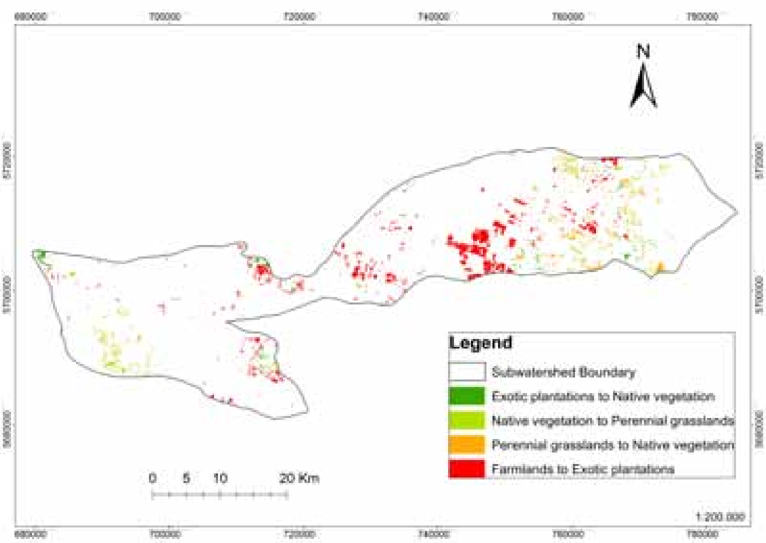

Figure 2. Key signals for land cover change in the sub-watershed of the Quepe River between 1994 and 2007.

were primarily pressured by "Exotic plantations" because of the comparative economic advantages and capitalization from forestry activities during the past decade in the region (Aguayo *et al*., 2009; CONAF-CONAMA, 2009; Schulz *et al*., 2010; ICET, 2013). Braimoh (2006) noted that the decrease in agricultural surface was also due to the concentration of production in more productive lands, thereby resulting in the abandonment of unprofitable lands and followed by an eventual shift towards other products (INE, 2007). In fact, according to the Agriculture and Forestry Census of 1997, the "Farmland" surface underwent a contraction; however, the yields per hectare (qmt ha^{-1}) for each type of traditional crop increased, and they even doubled in the intercensal period from 1997 to 2007 (INE-ODEPA, 2007; INE, 2007; INE, 2008; INE, 2011; ICET, 2013).

Meanwhile, the abandonment of "Perennial grasslands" to "Native vegetation" and the degradation of "Native vegetation" to "Perennial grassland" seemed to follow a pattern of abandonment of unproductive land and the preparation of new grazing land. In this respect, Díaz *et al*. (2011) noted that the recovery of native vegetation cover was associated with the abandonment of unprofitable lands, and both were due to industrialization and urbanization of the area. Moreover, the revegetation of "Exotic plantations" to "Native vegetation" may be related to the harvest from lands that are home to exotic plantations, in which shrubland emerges as an alternative ecosystem until it is prepared for the next generation of exotic plantations.

The main conclusions indicate that the methodology used allowed for the identification of systematic transitions that occurred in the study area for the period between 1994 and 2007. The results confirmed a tendency towards the reduction of agriculture areas and livestock and increased exotic plantations use on surfaces intended for agricultural use. Specifically, the systematic transitions, and therefore the key signals of LULC change in the Quepe River sub-watershed, were as follows: (1) the conversion, at a rate gain of 384 ha year^{-1}, of 3.11% (4986 ha) of "Farmlands" to "Exotic plantations", (2) the abandonment, at a loss rate of 119 ha year^{-1}, of 0.96% (1545 ha) of "Perennial grasslands" to "Native vegetation", (3) the degradation, at a loss rate of 93 ha year^{-1}, of 0.75% (1207 ha) of "Native vegetation" to "Perennial grassland", and (4) the revegetation, at a rate gain of 60 ha year-1, of 0.49% (778 ha) of "Exotic plantations" to "Native vegetation" (which had the weakest signal). Therefore, the

Table 5. Primary systematic transitions based on losses between categories for the period of 1994-2007.

Transition	*Vo*	*Ve*	*Vo – Ve*	*Vo-Ve/Ve*	Interpretation
Native vegetation 1994 to farmlands 2007	2	3.09	-1.09	-0.35	When the native vegetation is lost, it is not replaced by farmlands
Farmlands 1994 to native vegetation 2007	4	4.7	-0.7	-0.15	When farmlands are lost, it is not replaced by the native vegetation
Native vegetation 1994 to exotic plantations 2007	1.04	0.37	0.67	1.79	When the native vegetation is lost, it is replaced by exotic plantations
Farmlands 1994 to exotic plantations 2007	3.11	1.31	1.8	1.38	When farmlands are lost, they are replaced by exotic plantations
Perennial grassland 1994 to farmlands 2007	0.28	0.92	-0.64	-0.69	When perennial grasslands are lost, they are not replaced by farmlands
Perennial grassland 1994 to native vegetation 2007	0.96	0.4	0.57	1.42	When perennial grasslands are lost, they are replaced by the native vegetation
Native vegetation 1994 to Perennial grassland 2007	0.75	0.3	0.45	1.5	When the native vegetation is lost, it is replaced by perennial grasslands
Exotic plantations 1994 to native vegetation 2007	0.49	0.24	0.25	1.03	When exotic plantations are lost, they are replaced by the native vegetation

change in land use is linked to the socioeconomic aspects of the study area; this shows the importance of identifying the impact of production decisions on the structure and function of the agroecosystem, thus allowing for the development of public policies that adequately respond to trends in land use.

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Resumen

P. Saavedra Briones y A. Sepúlveda-Varas. 2016. Transiciones sistemáticas en cobertura y uso del suelo para sub-cuenca pre andina de alta intervención antrópica, Región de la Araucanía, Chile. Cien. Inv. Agr. 43(3):396-407. Estudios de los cambios en el uso de la tierra permiten comprender la configuración actual del paisaje e identificar los impactos ambientales y sociales que se asocian a estas transformaciones. Diversos autores describen "transiciones" como un proceso de cambio que transforma el paisaje, donde las "transiciones sistemáticas" son impulsadas por procesos estables y graduales. El objetivo de este estudio es determinar la trayectoria y magnitud del cambio de cobertura y uso de la tierra para el periodo 1994-2007 en sub-cuenca pre-andina de uso intensivo en el centro-sur de Chile y analizar las transiciones sistemáticas más significativas entre tipos de cobertura. Los resultados obtenidos confirman la reducción de áreas destinadas a agricultura-ganadería y el aumento de áreas de uso forestal: conversión, a una tasa de 384 ha año^{-1}, de "Cultivos y pastizales naturales" a "Plantaciones forestales"; abandono, a una tasa de pérdida de 119 ha año^{-1}, de "Praderas perennes" a "Bosque nativo y matorrales"; degradación, a una tasa de pérdida de 93 ha/año, de "Bosque nativo y matorrales" a "Pastizal perenne"; y revegetación, a una tasa de ganancia de 60 ha año^{-1}, de "Plantaciones forestales" a "Bosques y matorrales nativos". Así, debido a los nuevos patrones y tendencias en el uso de la tierra se reafirma la necesidad de contar con estudios sobre el estado actualizado de los recursos naturales, en particular el recurso suelo. Este trabajo, representa una herramienta de apoyo tanto para la gestión sostenible de un territorio como para la toma de decisiones sobre el uso de la tierra.

Palabras clave: Cambios cobertura de la tierra, Chile, LULC, planificación uso de la tierra, transiciones sistemáticas.

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