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STABILITY CYCLES, AND FAST-SLOW CHANGES AND VARIABLES IN LANDSCAPES OF THE CONCEPCION METROPOLITAN AREA [1]

USING THE STUDY OF SOCIO-ECOLOGICAL SYSTEMS: AN EXPLORATORY ANALYSIS

CICLOS DE ESTABILIDAD, CAMBIOS Y VARIABLES LENTAS-RÁPIDAS EN EL PAISAJE DEL ÁREA METROPOLITANA DE CONCEPCIÓN. A PARTIR DE ESTUDIOS DE SISTEMAS SOCIO ECOLOGICOS: UN ANÁLISIS EXPLORATORIO

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Los paisajes son capaces de maximizar sus fortalezas en momentos de estabilidad al desarrollar de manera profunda su carácter y, así, manejar las presiones o disturbios que generan cambios en los Sistemas Socio Ecológicos (SSE) en sus variables lentas y rápidas para evitar su transformación. Las variables rápidas son aquellas que explican los cambios de corto plazo y procesos violentos de ruptura en los ciclos de estabilidad/cambio en las temáticas de desastres naturales. Por su parte, las variables lentas corresponden a aquellas que explican los cambios a largo plazo y procesos más complejos en los ciclos de estabilidad/cambio. El trabajo que sigue se abocó al estudio del Área Metropolitana de Concepción (AMC), Chile, la cual ha sufrido cambios relevantes a lo largo de su historia, pero no ha sido estudiada como un SSE en sus variables lentas y rápidas. De forma exploratoria, se realizó una revisión literaria de 150 artículos en las bases de datos científicas sin uso de software científico de apoyo, considerando como palabras claves “Concepción” y “Área Metropolitana de Concepción”. Como resultados principales, se destacan ciclos de fenómenos de corto plazo -variables rápidas- con gran impacto, ejemplificados en desastres naturales (terremotos, maremotos, inundaciones, incendios y sequía), y cambios en los planes de urbanismo (planes urbanos e higienismo), así como fenómenos de largo plazo -variables lentas-, con impactos más memorables en ciertas áreas clave: política (conquista y guerra entre indígenas/españoles/chilenos), economía (auge/caída de ciclos económicos) y medioambiente (intervención humedales, creación de diversas leyes de protección).

Palabras clave: sistemas socio ecológicos, Área Metropolitana de Concepción, paisajes, estabilidad, cambio

Landscapes can maximize their strengths in moments of stability by deeply developing their character and, thus, managing the pressures or disturbances behind slow and fast changes in the Socio-Ecological Systems (SES) to avoid their transformation. Fast variables explain short-term changes and violent rupture processes in stability/change cycles for natural disaster issues. On the other hand, slow variables explain long-term changes and more complex processes in stability/change cycles. The work below focused on studying the Concepción Metropolitan Area (AMC, in Spanish), Chile, which has undergone relevant changes throughout its history but has not been studied as an SES using its slow and fast variables. An exploratory literary review of 150 articles was made in scientific databases without using scientific support software, considering “Concepción” and “Concepción Metropolitan Area” as keywords. The main results highlight short-term phenomena cycles -fast variables- with a major impact, exemplified in natural disasters (earthquakes, tsunamis, floods, fires, and drought), changes in urban planning (urban plans and hygienism), as well as long-term phenomena -slow variables-, with more notable impacts in certain key areas, namely political (conquest and war between indigenous/Spanish/Chilean peoples), economic (boom/bust of business cycles) and environmental (wetland intervention, creation of different protection laws).

Keywords: socio-ecological systems, Concepción Metropolitan Area, landscapes, stability, change

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I. INTRODUCTION

The Concepción Metropolitan Area (AMC, in Spanish) (72ºW - 36ºS), like other Chilean metropolitan areas (Orellana & Gilbert, 2013), comprises several adjoining communes and has one of the largest populations in the country. Indeed, it has undergone a demographic transition with a sustained increase from 507,870 inhabitants in 1970 to 985,034 in 2017 (National Institute of Statistics [INE], 2017). It has also seen a sustained urban expansion (Rojas, Pino & Jaque, 2013), which has fragmented its natural coastal ecosystems, wetlands, and protected areas (Romero Aravena & Smith, 2009; Rojas *et al*., 2006), generating an effect of confinement by pressuring its public property against urban areas (Jaque, Ojeda & Almendra, 2020). Likewise, it has also been considered in the specialized literature as an area with multiple threats (Araya, Metzger, Stuart, Wilson & Carvajal, 2017; Garreaud *et al*., 2020; Mardones & Vidal, 2001), both because of its Mediterranean climate (Sarricolea, Herrera & Meseguer-Ruíz, 2016), and for being inserted between two large geomorphological units, the coastal plains, and the coastal mountain range.

As for its economy, this has been based on the import-export of natural resources through their exploitation or use. Its services include malls, clinics, hospitals, universities, and government offices, and its tourism sector is based on its wide-open beaches (Rojas Quezada, Muñiz Olivera & García-López, 2009). This has been to the detriment of its traditional agricultural and peasant economy, which has declined to the former's benefit (Torres, Azócar, Rojas, Montecinos & Paredes, 2015; Hernández, 1983).

The AMC is also facing the challenges of climate change (Sarricolea *et al*., 2016; Garreaud *et al*., 2020; Gallardo Klenner, 2016), which adds uncertainty to its analysis, considering the unsustainable nature of the urban growth planned so far (Rojas, Pino & Jaque, 2013), and its abuse of resources in its natural systems (Torres *et al*., 2015; Hernández, 1983). These systems have cumulatively and negatively altered their properties. However, so far, they have avoided forced transformability, that is to say, the creation of "a fundamentally new system as the ecological, economic, or social conditions - including political ones - make the existing system unsustainable" (Walker *et al*., 2006, p. 3).

Based on this context, the objective of this article is to identify and make an exploratory analysis of the cycles of stability–change, as well as the slow-fast variables in the AMC landscape, using Socio-Ecological Systems or SESs as a theoretical basis (Hertz, García & Schlüter, 2020). It also proposes identifying key elements that configure the AMC as an SES because it has only been recognized as a metropolitan area from urbanism, and from geography, as part of the Biobío basin and one of the last Mediterranean climate zones in the country. To do this, 150 articles from indexed journals, in Spanish and English, were analyzed through a literary review with two key terms: "Concepción" and "Concepción Metropolitan Area". The working hypothesis is that the SESs in the AMC are subject to fast changes, followed by long cycles of stability, whose slow drivers are mostly of anthropic origin and fast are mostly of a natural origin, that is to say, the landscapes of the AMC will evolve rapidly without an SES perspective that sustainably incorporates the key concepts, creating unstable landscapes in their natural and human systems.

The importance of this work is that it allows, based on the available bibliographic evidence, identifying and relating landscape variables with the growth of the AMC, which would constitute the evidence needed to move toward sustainable and resilient urban development. The theoretical framework is presented below, whose focus lies in the SES, before then outlining the methodology used in the literature review and the results, which are finally discussed and concluded.

II. THEORETICAL FRAMEWORK

SES studies are found in the interaction between natural and social sciences (Berkes Colding & Folke, 2011) and try to respond to the requirements of a planet that is immersed in uncertainty, dealing with phenomena that the human species does not understand (Intergovernmental Panel on Climate Change [IPCC], 2007; Foley *et al*., 2005; Kirksey, 2021). SSES are defined as:

> complex adaptive systems in which humans and nature are deeply intertwined, and which consist of a complex network of ecological-social relations in constant evolution, and need to be conceived as an integrated system, rather than two systems that exist independently (Hertz *et al*., 2020, p. 2)

They are based on key concepts from the General Systems Theory such as processes, events, stability, resilience, transformation, continuous changes, dynamism (Mancilla García, Hertz, Schlüter, Preiser & Woermann, 2020; Holling, 2001), multi-actors, multi-agencies/agents and multi-scales (Elsawah, Guillaume, Filatova, Rook & Jakeman, 2015) (Figure 1). This conception differs from other interdisciplinary models such as the FES-system (FES, 2021), where systems are understood as intertwined organisms. Likewise, it differs from the coupled systems (*coupled human-landscape systems*) that are based on

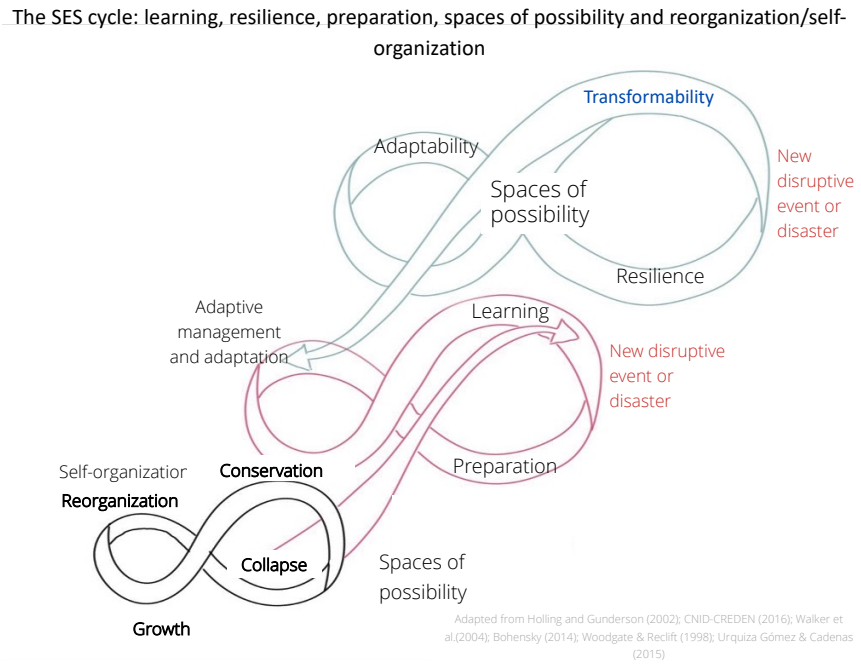

Figure 1. Outline that comprises the operation of feedback loops and the stages that SESs undergo. Source: Preparation based on Holling and Gunderson (2002, p. 34); CNID-CREDEN (2016); Bohensky and Leitch (2014); Woodgate and Reclift (1998); Urquiza Gómez and Cadenas (2015).

mathematical modeling to understand how the physical dynamics of landscapes influence human systems (Werner & McNamara, 2007). It is also distinguished from the concept of landscape, which corresponds to a set of physical-human elements in permanent transit (Ingold, 1993; Nogué, 2014).

In this sense, all the aforementioned models argue that natural and human systems closely interact with one another by establishing positive or negative feedback loops (Schoon & van der Leeuw, 2015), that is, they have cycles that allow their positive permanence through learning, resilience, and adaptability, or, on the contrary, have negative cycles that generate collapses in complex societies (Tainter, 1988; Diamond, 2010) that can lead to transformability (Figure 1). As a result, the SESs move between cycles of stability and change (Hertz *et al*., 2020), which are described below:

- **Stability cycles:** long-lasting stages populated by slow variables, namely, those phenomena that are grouped, according to their nature, into political, economic, and environmental, that explain long-term changes and complex processes and where the components of natural and human systems have characteristics that make them recognizable for long enough to be studied. For example, in the case of human systems, these stability cycles correspond to historical periods, and in the case of natural systems, ecosystems. In them, it is also possible to find the idea of *biostasis* and *homeostasis*, which has to do with the capacity - applicable to the SESs - to self-regulate once a change has occurred within the same limits that the system allows (Arnold and Osorio, 2008), that is to say, stability is what the identity of a system itself defines (Rubio, 1996).

- **Cycles of change:** these are those periods characterized by fast variables comprising disruptive events that present challenges to the SESs that break with the previous stability, as they offer them possible spaces to adapt, learn lessons, be resilient, prepare, collapse, or transform definitively. A concrete example of a cycle of change occurs with earthquakes that, unexpectedly, reveal whether the SESs have positive or negative feedback loops. If they are positive, they will be able to be resilient or adapt by moving to a new stability cycle, maintaining their main components in their natural and human systems. In the event of an earthquake, reconstruction work will begin quickly. If the cycles of change are negative, they will harbor collapses in both systems proving that they were not able to learn lessons and will transform into new SESs, whose non-human and human components

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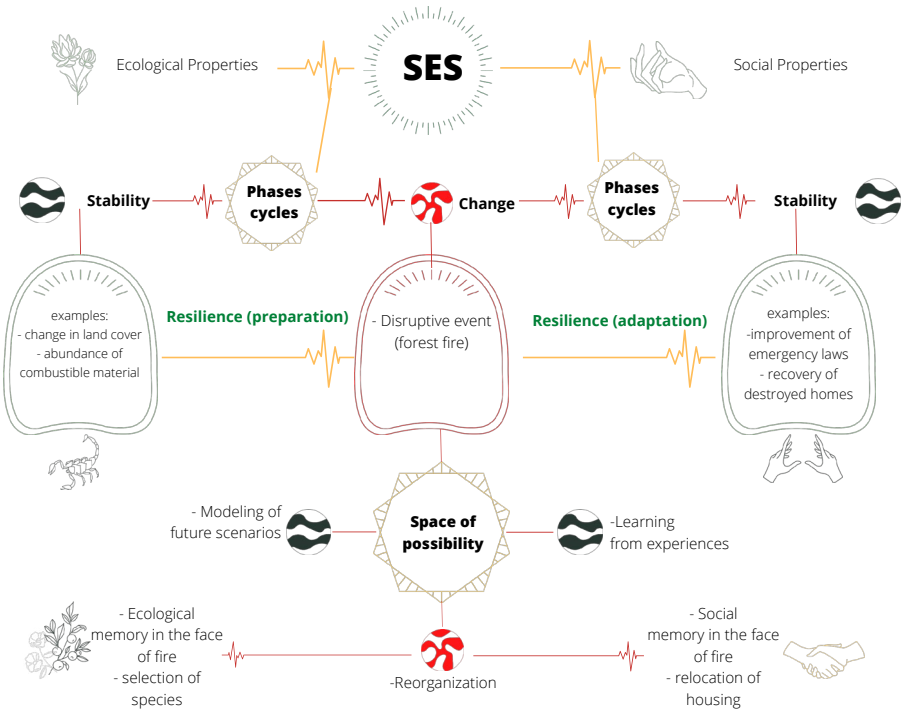

Figure 2. Abstract outline that identifies the cycles of stability and change in the SESs, taking as an example, a disruptive event in the cycle of change, in this case, a forest fire. Source: Own preparation.

> will not be adequately prepared. In the case of the earthquake, the political and social instability exacerbated after the disaster will lead to problems of urban violence, contamination, and migration problems.

All-in-all, the concept of stability is a topic of discussion that has not been settled. One of the positions that stand out is that natural and human systems would not be stable, but "meta-stable" (Winder, 2007), and would create a dynamic biosphere where living beings would interconnect in a complex network of relationships (food, social, etc.) (Capra, 1998). In contrast to this, Grimm, Schmidt, and Wissel (1992), Ludwig, Walker, and Holling (1997), Cumming (2011), and Iannucci and Munafò (2012) follow a more traditional position by considering stability as a concept that has its simile in a static well where systems strive to remain despite constant changes. In this exploratory article, the position of Cote and Nightingale (2012) is chosen, who consider stability as a moving baseline comprising multiple states, which would theoretically allow all SESs to go through stages or cycles of stability that can be studied at different times (Figure 2).

IV. METHODOLOGY

In this qualitative study, a literature review was carried out (Arksey & O'Malley, 2005; Arts *et al*., 2017; Pullin & Stewart, 2006) that contemplated three stages developed during 2020 - 2021:

- *Stage 1: Review question selection - search term:* The Web of Science (WOS), SCOPUS, and Google Scholar databases were used to search for the keyword "Concepción", which was supplemented with similar terms such as: "Área Metropolitana de Concepción", "Metropolitan Area of Concepcion" and "Concepción Metropolitan Area". Related terms such as "changes", "cycles" or "SES" were also considered if the former did not bear fruit. More than 300 selected articles were fully reviewed taking into account the keywords of each article, abstract, title, and development. These were accessed virtually from the Library of the Pontifical Catholic University of Chile.

- *Stage 2: Selection criteria or filters:* Once the articles with the keywords had been identified, they were subjected to new exclusion filters and organized in an Excel©

Cayucupil-Chile

•19th Century, 1857 – Chilfón del Diablo Mine, 1869 – Foundation of Cayucupil, 1880 Sleepers plantation.
•1910 – Arrival of Cattle farming; 1920 – Cereal crop agriculture, 1939 – Creation of Nahuelbuta National Park; 1940 Creation of BIMA Forestry Company
•1950 – New cereal crop farming, Mininco Forestry Company, and Forests Law (afforestation with pine trees)
•1960 Coñihual Forestry Company; 1962 Agrarian Reform; 1967 Forest surface data (INFOR)
•1971 FASA; 1974 Forestry Development Law; 1979 Intensification of Forestry Plantations.
•1980 Native forest surface data; 1983 Reduction of Nahuelbuta Park's area; 1984 Forestal Sur (Forestry Company); 1985 Mininco Forestry Company, and increase of single-crop farming.

Murcia - España

- Phase 1: Pre-Muslim period > 713 AD
  - Territorial development of large coastal towns
  - Natural drivers of dynamic change (droughts and floods)
- Phase 2: Muslim period (713-1243)
  - Muslim colonization
  - Demographic increase and foundation of Murcia
  - Development of hydraulic engineering
  - Natural (floods) and sociopolitical (war conflicts) drivers of dynamic change
- Phase 3: Christian conquest (1243-1492)
  - Depopulation, black plaque, plagues – hunger and war with the Kingdom of Aragon
  - Extension of watering surface (15th century)
  - Silk industry

Figure 3. Extracts from the results of the analysis model used to analyze SESs in Chile, according to Quiñones et al. (2017), and, in Spain, according to Gutiérrez et al. (2015). Source:Images of Scott Zona - Araucaria araucana 1, CC BY 2.0 (https://commons.wikimedia.org/w/index.php?curid=17346247) and José García, CC BY-SA 3.0 (https://commons.wikimedia.org/w/index.php?curid=31821325).

sheet, a process from which 150 selected articles were obtained. The criteria used were the following:

- must be a peer-reviewed article (not a thesis, book, university journal or magazine article, press release, conference abstract, or editorial);
- must be available on the Internet (not physical paper or files);
- must contain the full search terms defined in stage 2;
- must be based on the Chilean AMC and not on other cities with the same name (e.g., Concepción del Uruguay).

- *Stage 3: Analysis and communication of results:* In this exercise, the agents, stability–change cycles and fast–slow variables studied were identified following the model of Quiñones et al. (2017) and that of Gutiérrez, Suárez, and Vidal-Abarca (2015) (Figure 3). The results were communicated through a timeline (Figure 4) and a summary table (Table 1), with the main findings such as laws, socio-economic activities, agents, and/or relevant natural disasters:
  - For human systems, the cycles of stability and change were considered, dating them according to the available literature. For example, within the articles that address the AMC in the political sphere, it is highlighted that between 1603-1687 there was a cycle of stability associated with the fortification of the Biobío coastal area, then a cycle of changes led by indigenous uprisings, before giving way to a cycle of stability with the creation of border cities.
  - As for natural systems, their cycles of stability and change have very different time scales from the human ones studied separately in the different natural sciences, and, therefore, socio-natural disasters were chosen as representative for the cycles of change of these systems. For example, for natural disasters, there is a period of stability associated with the Regulatory Plan of Conception of Emilio Duhart, which is wiped away by the earthquakes and tsunami of 1960-1962, before a period of stability based on the reconstruction with the Intercommunal Regulatory Plan of 1963.
  - For both systems, slow-fast variables were considered, which were identified by considering keywords in the texts (*screening*) that were categorized and organized chronologically in Excel© (Figure 4). For example, for the text by Leonel Pérez Bustamante and Edison Salinas

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Varela (2007), "Urban growth and globalization: transformations of the Concepción Metropolitan Area, Chile, 1992-2002", keywords were identified (in red) associated with a slow variable that covers the economic area, from 1950 to the present day:

* "...In Concepción... the metropolitan dimension clearly begins with the installation of the Compañía de Aceros del Pacifíco – *Pacific Steel Company* (CAP) in Huachipato, around 1950..."

¤ Agents are those anthropic elements associated with people, organizations, or institutions that can lead to stability cycles or new changes in natural and human systems.

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V. RESULTS.

Cycles of stability and change

The articles analyzed express an anthropic perspective and identify cycles of change-stability that have very different feedback loops from agents, laws, and economic activities. This happens because they are short-lived cycles originating in natural systems, namely, catalyzing events for natural systems grouped into earthquakes, tidal waves/ tsunamis, droughts, forest fires, floods, and tornadoes. As a sample, in 1751 there was a change event caused by a tidal wave that broke with the previous stability of the city in Penco, so when the earth stopped shaking it allowed human systems to move the population to the Mocha Valley in 1754 (Salinas & Baeriswyl, 2017) (Table 1).

Some exceptions were identified in the AMC, such as the intervention-occupation processes of wetlands since 1955, and those for soil erosion since 1960, which occur to this day. Both are an exception because they are elements that do not show signs of going through stability cycles, so they could be catalysts for the transformability of the SESs unless they are stabilized with anthropic management based on ecological criteria. The results report that their space of possibility strongly depends on their surrounding historical and social conditions, and also coincide with traditional historiographical and economic references (Salazar & Pinto, 1999-2002):

- a period marked by bellicosity between indigenous people and Spanish conquistadors, from 1554 to 1800, which led cities to periods of construction and reconstruction;
- a period of formation of republican agents associated with the agricultural exports of vineyards-wheat initiated by the Bishopric of Concepción in 1780 and those by the bourgeoisie with the coal mines in 1850. This ended with the great migrations of peasant laborers to the flourishing industrial cities of the AMC, between 1960 -1970;
- a period of scientific and cultural formation that began with the founding of the El Sur Newspaper, in 1900, and the University of Concepción in 1919. It continues to this day with the arrival to the AMC of creative classes with a high educational and economic level, both from other regions of Chile and from nearby provinces (Los Angeles, Chillán, Laja, San Carlos, and Yungay).

The legislation (Table 1) that has affected the human and natural systems mentioned in the articles reviewed, coincides with the different traditional political periods studied by Salazar and Pinto (1999-2002), among other authors. These are linked with:

- a period of war where the Mapuche–Spanish border is established (1554-1850);
- a Chilean republican period that begins with the first Civil Code (1856) and the first police of the Province of Concepción (1830-1860), and ends with the 1973 coup d'état;
- a period where the appearance of environmental-extractive policies that began with the agrarian reform of Eduardo Frei M. - Salvador Allende (1964-1973) and DL 701 promulgated in 1974, and continue to this day with the successive improvements to Law 19.300, the General Environmental Law (1994).

The socio-economic activities of human systems are directly related to the laws and policies identified by Salazar and Pinto (1999-2002). There the following stand out:

- a first period where an economy of essential goods production for survival in times of war predominates (fishing and farming) that lasts until 1830, expanding throughout the territory;
- a second period to establish a proto-industrial economy of exploitation of natural resources (fishing, wheat, and coal) which lasts until 1930;
- a third period of recovery after the 1929 crisis, focusing on the import substitution economy where the extractive industrialization of coal, steel, and fisheries is consolidated, which remains until the global recession of 1982;
- the current period where this area is inserted in a neoliberal global economy that restricts its industries through import substitution to become a center of services – consumption. A new type of extraction and processing of forest-fishery natural resources begins, which takes shape with the privatization of Forestal Arauco between 1977-1979, is consolidated with the closure of coal mines between 1994-1997, and continues to this day, spreading throughout the territory.

Topic.	Year	Initial stability	Change	Final stability	Agents
Natural disasters	1751	City in Penco	Tidal Wave	Transfer to the Mocha Valley in 1754	Governors and intendants
Natural disasters	1835	Charles Darwin's Trip to Chile	Earthquake and tsunami	Development of theories of evolution and plate tectonics	Charles Darwin
Urban development	1856	Conservative Republic (1830-1860). Civil code.	Urban Plan for Concepción by Pascual Binimelis	Urban sanitation and improvement. Organization of agricultural and semi-spatialized peonage in artisanal work	Governors and intendants, urban planners
Natural disasters	1960-1962	Regulatory Conception Plan by Emilio Duhart	Earthquake and tsunami	Intercommunal Regulatory Plan of 1963	Governors and intendants
Natural disasters	2006	Ribera Norte Urban Recovery Program (PRURN) since 1990	Floods	Management of Biobío River's Northern Bank has decreased the risk of seasonal flooding, controlling the risks of mass embankment removal and hill escarpments	Governors and intendants, urban planners
Natural disasters	2010	PRC (Communal Regulatory Plan) with risk studies	Earthquake and tsunami	Tsunami-resistant housing structures in Tomé and Tumbes	Governors and intendants, urban planners, Neighborhood Councils
Political	1605-1803	Mapuche Spanish border	Destruction of the city by indigenous people in 1554-1555	Reconstruction in 1557	Conquistadors, indigenous people
Political	1603-1687	Fortification of the coastal zone	Indigenous uprisings	Creation of border cities	Conquistadors, indigenous people
Economy	1830-1930	Frontier economy opening up to export (wheat - cattle - wine)	The advance of the railroad and bridges over the Biobío River	Urbanization expanded to other communes, formation of the AMC	Government of Chile, Chilean and foreign mining bourgeoisie (Cousiño-Schwager), Municipality
Economy	1850-1997	Mining boom Lota Coronel	Closure of Puchoco and Lota mines	Conversion of cities to "dormitories"	Government of Chile, Chilean and foreign mining bourgeoisie (Cousiño-Schwager), Municipality

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Topic.	Year	Initial stability	Change	Final stability	Agents
Political	1900-today	Formation of the commercial entrepreneurship of Concepción in the final decades of the nineteenth century	Foundation of the University of Concepción in 1919, creation of the El Sur Newspaper	Population with a high educational level migrates to Gran Concepción, especially from Los Angeles, Chillán, Laja, San Carlos, etc. Formation of a creative class	The University of Concepción, local elite, Freemasonry
Economy	1930-today	ISI-type industrial development in the intercommunal area. Railway progress	Decline in industrial development with the 1982 crisis and the neo-liberalization of the economy after the coup of 1973	The AMC assumes a role as a distribution, services, and consumption center until today	Huachipato CAP Steel works, San Vicente Port, Huachipato homes, Agüita de la Perdiz, Paños Bellavista Factory, Tomé, CORFO, Aurora de Chile
Environmental	1955-1980	Occupation and intervention processes in the wetlands of the AMC	Erosion, mass removal processes, drought	Accelerated urbanization and forest plantations, homogenization of the landscape. 1st survey and diagnosis of the state of maritime-coastal wetlands.	Neighborhood councils, Chilean Government, MOP (Public Works Ministry), MINVU (Housing and Urbanism Ministry), forestry companies (CMPC, ARAUCO)
Environmental	1994-today	The repertoire of the 1992 Legislation of environmental relevance in force in Chile	Law 19.300 on General Environmental Guidelines	Increase of planning instruments oriented to caring for the environment and the development of the EULA Center	Eula Center, urban planners, mayors, governors, universities
Natural disasters	2017	mega drought	Mega Fire 2017	Erosion in fire zones, the progress of urbanization/forestation, and the loss of peasant economies	Forestry companies, governors, intendants, small farmers and landowners, Neighborhood Councils, Chilean Government MOP, MINVU, forestry companies (CMPC, ARAUCO)

Table 1. Summary of the stability-change cycles and events obtained from the literature review. Source: Own preparation based on literature review. Note 1: Fast variables have changes in years or months and slow variables have changes in decades or centuries. Note 2: Human actors can be individuals or institutions.

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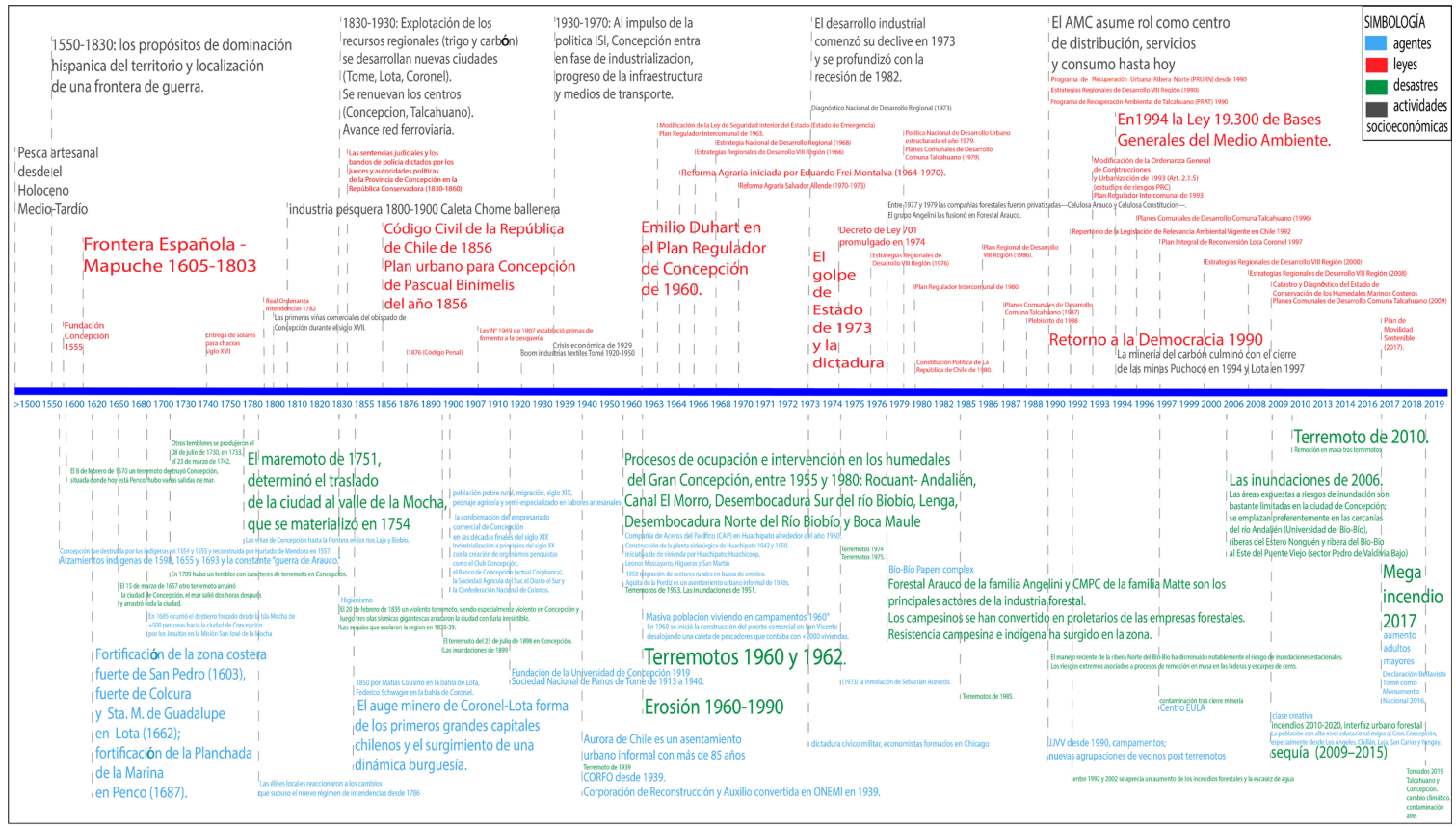
Slow and fast variables from the SSEE perspective

Two types of variables were observed in the SESs called slow and fast (Walker *et al*., 2006). Fast variables (Figure 4) are those that explain the short-term changes and the violent rupture processes in the stability cycles and, in this case, were observed in the themes of natural disasters (earthquakes, tidal waves, floods, fires, and drought) and those of urbanism (e.g., urban plans and sanitation). The slow variables, on the other hand, correspond to long-term changes and complex processes in the cycles of stability/change, which were grouped in the political (war between indigenous/Spanish/Chileans), economic (boom/bust of economic cycles), and environmental (wetland intervention, creation of different protection laws) spheres.

The variables of non-human systems are considered as slow variables, since their stability is longer lasting than their changes, which have been caused, as was found, entirely by external pressures such as earthquakes, tsunamis, extreme climatic events, and human actions (e.g., management of the Biobío North Bank and port construction). Likewise,

Figure 4. A timeline that indicates the slow and fast variables in the AMC's SESs based on the literature review. Source: Own preparation based on literature review.



Elementos del Área Metropolitana de Concepción que constituyen un Sistema Socio Ecológico obtenidos desde la revisión bibliográfica de 150 artículos en las bases de datos WOS, GOOGLE SCHOLAR y SCOPUS (2020-2021).

long-standing phenomena associated with the land were noticed (mass removal processes, drought, erosion in fire zones, and coal extraction); an increase/decrease in sedimentary concentrations in the water bodies of the Biobío, Andalién rivers, and their wetlands, as well as the anthropic exploitation of trees (forest plantations) and animals (livestock, fishing, and algae collection).

VI. DISCUSSION

The slow-fast variables have been studied from the SES perspective, mostly through mathematical modeling, which makes it difficult to access qualitative models or those focused on understanding the entire phenomena (Hertz *et al*., 2020; Walker, Holling, Carpenter & Kinzig, 2004). The Quiñones *et al.* (2017) model does something different with the Cayucupil basin in Chile by complementing satellite image studies with an in-depth literature review to explain the proposed SES. Similarly, in the United States, it is shown how forest fires (disruptive events that generate changes) can be understood from the SES perspective (Steelman, 2016). Another example is given in Spain, where the cycles of stability and change in the SESs have been addressed using ecosystem services and a bibliographic review of periods spanning 2,000 years (Gutiérrez *et al*., 2015) allowing for a more complete analysis of the cycles since more information is available from chronicles and archives that narrate the history from the anthropocentric perspective of both systems.

On the other hand, the variables associated with natural or non-human systems are more difficult to establish without the help of areas associated with landscape ecology and General Systems Theory, which focuses on understanding the dynamics of different ecosystem processes (Holling, 2001) incorporating economics, resilience, and governance (Berkes et al., 2003). Solutions have been proposed with the new multidisciplinary, multi-scalar, and multi-spatial intersections (Goldman, Nadasdy & Turner, 2011), where researchers work with other ontologies:
"You will follow all matter, through every material, and understand the earth systems of our collective now without dividing them into the irrelevant and outdated categories of 'society' and 'nature'. You will know that fences don't stop earthly flows..." (Green, 2021, p.1).

Some examples of this desire to cross frameworks have been given in the Agrarian Change Project which integrates SES methodologies into the multifunctional landscapes of Africa (Sunderland *et al.,* 2017). Likewise, interdisciplinary methods have been applied in Pakistan to evaluate Social-Ecological Landscape Systems (SELS) in aspects of mobility and degree of urbanization (Abbas, Shirazi & Qureshi, 2018). The Wadden Sea, which is a protected area shared between the Netherlands, Germany, and Denmark, is added to these (Sijtsma, Mehnen & Angelstam, 2019).

In this exploratory study, the cycles of stability, changes, and slow and fast variables in the AMC's SESs are discussed, based on a review of national and international academic production that focused on this area in its numerous sources. In this sense, it is observed that environmental history and case study historiographic works have contributed to understanding the area, through a qualitative approach that allows combining scientific sources of a diverse nature, to originate an analysis of interdisciplinary characteristics. This opens up possibilities of applying conceptual models that establish scenarios and forecasts of what could happen there in the future, in addition, to promoting improvements in territorial planning, development policies, and economic incentives and pointing to ways of life in human systems with fewer negative feedback loops. This means opening up to the idea that systems have cycles of stability and change that can be taken advantage of to move towards adaptable, resilient SESs, which include a non-speciesist posthumanist perspective and that are capable of handling significant learning. In this sense, for example, the legislation that has required higher levels of earthquake resistance in buildings (NCh 433 and NCh2369) and the determination of non-construction zones that are included in the regulatory plans stand out. Both have made it possible to save countless human and non-human lives, reduce post-disaster reconstruction costs, and promote cycles of change with fast variables that allow fluent transitioning to stability cycles.

VII. CONCLUSIONS.

From the work carried out, it can be pointed out that the working hypothesis is fulfilled, namely, that the SESs in the AMC are subjected to fast changes followed by long stability cycles whose slow drivers are, for the most part, of anthropic origin, and their fast ones are also mainly of a natural origin. Among the findings of the study, it is highlighted that, in human systems, the catalysts of changes can be grouped into laws, agents, and socioeconomic activities, and, in natural systems, are only natural disasters. The fast variables were appreciated in natural disasters for natural systems and changes in urbanism. The slow variables for human systems were grouped into political, economic, and environmental variables. In this line, cycles of stability and changes and slow and fast variables that influence these cycles for the AMC in Chile were identified. These results constitute a contribution to the extent that they point to the availability of the concepts analyzed from the perspective of the SESs and their integration into the available literature on the AMC, which has

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different temporalities. The limitations of this study are given by the areas that have been studied in this territory.

As a reflection, it should be mentioned that interdisciplinary integration becomes arduous to survey the knowledge of the SESs from a point of view that is not purely anthropic, mathematical, or ecological, since the reviewed articles refer to their own areas, concepts, ontologies, and epistemologies. This makes a multi-scalar and/or multidisciplinary process difficult and, even more so, to incorporate the SES perspective for the general public and decision-makers in the AMC. In this sense, this work seeks to open the door for research such as those of Winder (2007), Iannucci and Munafò (2012), and Cote and Nightingale (2007) to be replicated in the AMC. They work across areas on systems theories, SESs, and historiography to understand how systems behave, a fact that is demonstrated in this article.

When looking at public policies, this article reveals the importance of natural disasters as a key element in the phases of change that were evidenced in the AMC. In this context, in recent years, in Chile, coordinated efforts have been made to integrate the concepts and processes that SESs provide through the formation, in 2016, of the National Commission for Resilience against Disasters of Natural Origin (CREDEN), under the auspices of the National Council for Innovation for Development (CNID); the creation, in 2019, of the Institute for Disaster Resilience (ITREND); and through the formation of the Interministerial Committee for Just Socio-Ecological Transition (TSEJ), in 2022. Thus, it is worth finishing with the words of the Minister of the Environment, Maisa Rojas:

> Just Socio-Ecological Transition is a concept that we have coined for a series of transitions that Chile has to go through and thus move from a situation of environmental degradation, climate crisis, and destruction of biodiversity - affecting the population-, to a model where we give greater well-being to Chileans. (Ministry of the Environment [MMA], 2022)

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