Studies of Social Metabolism at the Commodity Frontiers of Peru

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THESIS TITLE

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To my father and Victoria

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Contents

Summary

The thesis aims to contribute toward improved understanding of complex ecological distribution conflicts at the commodity frontiers, where increasing metabolism in industrial societies is leading to increased environmental destruction in resource rich countries throughout the world. The thesis consists of three case studies of social metabolism in Peru (i.e. Camisea, Conga, and Sierra del Divisor). Analytical representations of the central economic processes are developed based on the flow/fund theory (Georgescu-Roegen, 1971) in order to explore the anatomy of these environmental conflicts. The thesis develops an empirical methodological contribution that combines two approaches: the environmental valuation triadics representation of economic purpose (Farrell, 2007) and the multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM) representation of economic process (Giampietro and Mayumi, 2000a, 2000b, 2009). That is, the social actor's economic purpose defines the boundaries of the economic process (i.e. frontier and duration), and therefore, the process elements identities in terms of flows and funds. This can be understood as the pre-analytical step of the MuSIASEM representation of an economic process.

The Camisea case study analyzes the energy-water-mining complex, and poses the specific question: What are the long-term national energy system implications of the government-supported growth of the mining sector? This question is addressed by analyzing interactions between funds of human economic activity and flows of exosomatic energy across scales of the Peruvian economy, in 2000 and 2010, with a projection for 2020. The MuSIASEM empirical results indicate: (1) the extremely high electricity metabolic rate (eEMR) of the mining sector (61.6 MJ/h in 2010), which was found to be 11 times the eEMR of the building and manufacturing sector; and (2) the potential increase of the flow share of electricity used by the mining sector, which could reduce the availability of Camisea natural gas –the main fossil fuels reserve– for the rest of society. Based on these implications, it is argued that the Peruvian government strong support for growth of the mining sector may have to be reconsidered.

The Conga case study in the Andes explores the anatomy of the ecological distribution conflict between the mining corporation and the campesinos (peasants). By complementing the concept of Ricardian land—an indestructible fund—with the concept of land materials, which is susceptible to qualitative change, and therefore can be either a fund or a flow element of the economic process, we illustrate that the minerals extraction process of multinational companies, which treats this land material as a flow, stands in conflict with the milk production process of campesinos, because that process is using these land materials as a fund, that is, in order to make production possible. In other

words, from the perspective of campesinos (and the common sense) “el agua vale más que el oro” –that is, the market exchange value of gold is less important than the life support value of water (i.e. biophysical and spiritual).

The Sierra del Divisor case study in the Amazonia applies the MuSIASEM in a simplified way in order to describe key economic processes in two periods of time, before and after the potential construction of the transcontinental Brazil-Peru railway project that would cross the Sierra del Divisor tropical rainforest, representing a major change in the boundary conditions of the observed system. The economic processes studied in this case include: industrial soybean production in Brazil, alluvial gold mining extraction in Peru, fishing by native communities, rice production by small farmers, and hunting and gathering activities of indigenous people living in voluntary isolation.

Resumen

La tesis busca contribuir a un mejor entendimiento de los complejos conflictos ecológico-distributivos en las fronteras de extracción, donde el aumento del metabolismo de las sociedades industriales conduce a una mayor destrucción del medio ambiente en países ricos en recursos naturales alrededor del mundo. Se desarrollan tres casos de estudios – Camisea, Conga y Sierra del Divisor, los cuales se explicarán más adelante. Se utiliza la teoría de flujos y fondos (Georgescu-Roegen, 1971) para desarrollar representaciones analíticas de los procesos económicos centrales que intervienen en cada caso de estudio, de forma tal que se facilita la comprensión de la anatomía de estos conflictos socio-ambientales. La tesis presenta una contribución metodológica empírica que combina dos enfoques: las triadas de valoración ambiental para representar el propósito económico (Farrell, 2007) y el análisis integrado multi-escala del metabolismo de la sociedad y los ecosistemas (MuSIASEM, en inglés) para representar el proceso económico (Giampietro y Mayumi, 2000a, 2000b, 2009). En este sentido, el propósito económico de un actor social define los límites –frontera y duración– del proceso económico, y por lo tanto, las identidades de los elementos del proceso en términos de flujos y fondos. Esto puede ser entendido como la etapa pre-analítica de la representación MuSIASEM del proceso económico en cuestión.

El caso de estudio de Camisea analiza el complejo de energía-agua-minería y plantea la interrogante sobre cuáles son las implicancias de largo plazo en el sistema energético nacional del crecimiento del sector minero en Perú, favorecido por el gobierno. Esta pregunta se responde mediante el análisis de las interacciones entre el fondo de actividad humana y los flujos de energía exosomática a través de múltiples escalas de la economía peruana para los años 2000 y 2010, con una proyección al 2020. Los resultados empíricos indican: (1) el altísimo ratio metabólico de electricidad (eEMR) del sector minero (61.6 MJ/h en 2010), el cual resultó ser 11 veces el eEMR del sector de construcción y manufactura; y (2) el posible incremento de la proporción de electricidad utilizada por el sector minero, lo cual podría reducir la disponibilidad de gas natural de Camisea –la principal reserva de combustibles fósiles– para el resto de la sociedad peruana. Por lo tanto, se argumenta que el fuerte apoyo del gobierno al crecimiento del sector minero tendría que ser revisado.

El caso de estudio de Conga en los Andes explora la anatomía del conflicto ecológico distributivo entre la empresa minera y los campesinos. Se complementa el concepto de tierra Ricardiana –un fondo indestructible– con el concepto de materiales de tierra, el cual es susceptible de cambio cualitativo, y por lo tanto puede ser fondo o flujo del proceso económico. Desde la perspectiva de la empresa minera, los materiales de tierra son

considerados flujos del proceso de extracción de minerales, lo cual está en conflicto con la perspectiva de los campesinos, quienes consideran los mismos materiales de tierra como fondos del proceso de producción de leche fresca. En otras palabras, desde el punto de vista de los campesinos "el agua vale más que el oro", es decir, el oro como valor de cambio en el mercado es menos importante que el agua como valor de soporte de la vida, tanto biofísica como espiritual.

El caso de estudio de Sierra del Divisor en la Amazonia aplica una representación simplificada de MuSIASEM con el fin de describir los procesos económicos clave en dos períodos de tiempo, antes y después de la posible construcción del proyecto de ferrocarril transcontinental entre Brasil y Perú, que podría cruzar la Sierra del Divisor y los territorios Isconahuas. Los procesos económicos estudiados incluyen: la producción industrial de soya en Brasil, la minería de oro aluvial en Perú, las pesca de comunidades nativas, la producción de arroz de pequeños agricultores, y las actividades de caza y recolección de pueblos indígenas viviendo en aislamiento voluntario.

Chapter I

Introduction

The study of the inextricable relation between human society and its environment is a complex issue. Some professionals and academics try to reduce this complexity into a single unit of measurement (i.e. monetary values), and many public and private decisions are being made on this basis. Others understand the unavoidable uncertainties and multiple languages associated to complex living systems, and work on the development of new scientific knowledge with a plurality of perspectives. I recognize ecological economics and the social metabolism approach as part of the second group.

The present thesis aims to contribute to the study of social metabolism at the commodity frontiers (Moore, 2000)[1] of Peru. The general question is: How has increasing global demand for the materials and energy flows of modern industrial society is leading to socio-environmental conflicts in the local communities living at the commodity frontiers of Peru? Being guided by this question, the thesis seeks to develop an empirical methodological contribution with a focus on the representation of economic processes based on the theory of Georgescu-Roegen (1971), that is, the flow/fund model where: "Flows are elements that enter but do not leave the process, or conversely, elements that exit without having entered the process (e.g. natural resources, supplies, products, and wastes). Funds (e.g. capital, people, and Ricardian land) are elements that enter and exit the process unchanged, transforming input into output flow" (Mayumi, 1999: 181).

The ecological distribution conflicts (Martinez-Alier and O'Connor, 1996)[2] between large-scale corporations (e.g. mining, construction, and industrial agriculture companies) and local communities (e.g. peasants and indigenous people) arise both on the funds and the flows of an economy. For instance, conflict between mining companies and peasants in the Andes can be understood to be related to dispute over the identity of the mountains (i.e. the complex of rocks, land, and water) containing minerals commodities (e.g. gold, copper). For the miners these mountains are flow elements of their economic process, to be transformed into metals concentrates and wastes; while for the peasants the same mountains are fund elements of their economic process, to be maintained in order to reproduce the process of milk production in the future. This interpretation of how

[1] Moore (2000) uses the concept of commodity frontier for the study of world capitalist expansion and its structural tendency towards environmental degradation. The concept is based on world-systems concept of commodity chain.

[2] Marta Conde and Joan Martínez Alier from the EJOLT Project (http://www.ejolt.org/2016/04/ecological-distribution-conflicts/) describe this term as follows: "The term Ecological Distribution Conflicts (EDCs) was coined by Joan Martinez Alier and Martin O'Connor (1996) to describe social conflicts born from the unfair access to natural resources and the unjust burdens of pollution. Environmental benefits and costs are distributed in a way that causes conflicts. The terms socio-environmental conflict, environmental conflict or EDC are interchangeable."

environmental conflicts arise both on the funds and the flows of an economy can be related to the founding text on Political Ecology, written by Blaikie and Brookfield (1987), which is on soil erosion caused not by population pressure but economic production pressure – the soil is a fund.

The thesis consists of three research articles, each with particular purposes and methods, and all sharing a common theoretical approach that integrates attention to the social values (i.e. systems of value articulation) of conflicting social actors with the physical values (i.e. material and energy flows) of their respective economic processes, based on the flow/fund model (Georgescu-Roegen, 1971). The three case studies (i.e. Camisea, Conga, and Sierra del Divisor) are used to illustrate the thesis's methodological contribution, and reveal key characteristics of the social metabolism at the commodity frontiers of Peru.

Peru: Biological and Cultural Diversity with Commodities Extractivism

The biological diversity of Peru is the result of millions of years of evolution. The Andean mountains divide the Pacific Ocean coast from the Amazon forest, leading the country to be home to a huge variety of ecosystems. These features make Peru one of the countries with the greatest biological diversity in the world, with 20,375 plant species (including the agricultural diversity), 523 mammals, 1847 birds, 446 reptiles and 1070 marine fish (MINAM, 2014). The pre-colonial cultural diversity of Peru is the result of about 15,000 years of social change, from the first hunter-gatherer peoples; followed by a variety of agricultural societies in the Coast and Andes, beginning with Caral some 5,000 years ago, and followed by Chavin, Paracas, Nazca, Moche, Tiahuanaco, Huari, Chimu, Chachapoyas, Huanca, Aymara, Chanca, Quechua, among others, until the Tahuantinsuyo (i.e. the Incas) in the fifteenth and sixteenth centuries. In addition, the cultural diversity includes a variety of indigenous peoples in the Amazonia who are alive today, which are grouped into 13 linguistic families and about 60 ethnic groups (INEI, 2009). They are the Achuars, Ashaninkas, Matsiguengas, Shipibos, Isconahuas, and many others.

The Spanish invasion in 1532 represented the beginning of a major social change in the cultural, political, economic, as well as ecological characteristics of Peru. The economy during the colonial period was characterized by the extraction and export of precious metals (i.e. gold and silver) from mines in the Andes based on the forced labor of local people. After independence, in 1821, the economic system of extractivism continued with a diversification of commodities. For instance, the extraction of guano from the islands between 1840 and 1870 that contributed to agriculture production in Europe; and the extraction of natural rubber (*caucho*) from the Amazonia between 1880 and 1920, which was based on the forced labor of indigenous peoples (Basadre, 1968). Then, it was the land concentration process in the so called *haciendas* for the industrial production of sugar cane in the Coast and for agriculture and livestock production in the Andes. The latter is related to the socio-environmental conflict over grazing lands with the peasants called *huacchilleros* (Martinez-Alier, 1973).

The large-scale materials extraction of the mining sector began with the Cerro de Pasco Copper Corporation in 1922, followed by the Southern Peru Copper Corporation in 1954, both with a long history of environmental pollution and social conflicts that continue today with Volcan, Doe Run, and Grupo Mexico (EJOLT, 2016a). The minerals extraction processes expanded dramatically all over the Peruvian territory, after the neoliberal reforms in the decade of 1990 during the dictatorial government of Alberto Fujimori, now in prison for crimes against humanity. For instance, we have the cases of Newmont Mining Corporation in Yanacocha and Conga gold mines in the northern Andes, and Pluspetrol natural gas exploitation in Camisea in the southern Amazonia, both studied in the present thesis.

The expansion of the commodity frontiers in Peru also implies the construction of large-scale infrastructure for commodities transportation, energy generation, and water diversion required by the industrial agriculture and the energy-water-mining complex (Parker et al. 2015; Sharife and Bond, 2011). In order to take this into account the thesis analyzes the Transcontinental Brazil-Peru, Atlantic-Pacific railway (FETAB, in Spanish), which is a large-scale ground transport infrastructure project set to run between the Atlantic port of Santos (Sao Pablo, Brazil) and the Pacific port of Bayovar (Piura, Peru). The FETAB railway project, if built, would represent a sudden opening of a new frontier in Amazonia, which can be expected to facilitate timber extraction, burning of forest, the introduction of cattle ranching, plantations of eucalyptus, soybean, and palm oil, and eventually minerals extraction and hydroelectricity generation.

Moreover, severe ecological distribution conflicts are already present in other Amazonian frontiers of Peru. For instance, there are indigenous people living in voluntary isolation, which face external pressures due to new developments of extractive industries and infrastructure, such as the case of Camisea natural gas exploitation in the lower Urubamba River in Cusco. And, the deforestation of primary forest due to oil palm plantations for large-scale agro-biofuels production, which involve the Grupo Romero that is one of the largest finance and manufacturing conglomerates in Peru (EJOLT, 2016b). In addition, the illegal mining is growing rapidly in the regions surrounding the existing IIRSA[3] Southern Interoceanic Highway in the *Madre de Dios* region, with serious social and environmental impacts (Valencia, 2014; Asner et al., 2013).

[3] Initiative for the Integration of the Regional Infrastructure of South America (IIRSA).

In order to describe these conflicting social and physical relations between economic processes and their environments, the present thesis employs the concept of social metabolism, which is described next.

The concept of social metabolism

> "Ecological Economics provides a systemic vision of relations between the economy and the environment. The study of environmental conflicts then is therefore not just a collection of interesting anecdotes, but a part of the study the evolving confrontation between the economy and the environment. We see economies from the point of view of social metabolism. As is the metabolic profile of these economies, so are environmental conflicts."
>
> Joan Martinez-Alier (2010 [2002]: 43)

The concept of social metabolism can be understood as "the basic idea that the economy is physically embedded into the environment, that is, the economy is an open system with regard to the matter and energy" (Schandl et al., 2002: 5). In order to illustrate this concept, we may think about a dairy products factory, specifically, the production of evaporated milk, which is the dairy product consumed most widely in Peru. First of all, we need to define the boundaries of the economic process in question, which means the frontier and the duration. Putting aside the discussion on the nature of the boundaries of economic process for a moment, we may choose the factory's border and one day of production as the frontier and the duration, respectively. Then, we would see input/output flows of energy and materials between the factory and its environment, as well as a series of qualitative changes inside the factory. The inputs flows include fresh milk, packaging materials, maintenance supplies, water, fuels, and electricity, which are transformed into outputs flows of evaporated milk contained in cans and wastes. Then, we would see the fund elements of this economic process, which include different type of workers going in and out every day, who use the buildings, tools, machinery and Ricardian land area of the factory to transform the inputs into output flows. The basic idea of social metabolism is that the production process is inextricably linked with its biophysical environment, that is, the operation of the dairy products factory processes depend on the continuous exchange of materials and energy with its environment. Therefore, it is necessary to take into account the characteristics of the biophysical environment, something that is not well considered by standard economists when they focus mainly on market exchange values instead of a plurality of values, which include biophysical values as well as cultural and political values.

For instance, if we expand the scale of observation of the evaporated milk production process in order to see more characteristics of its environment, we can analyze the fresh milk production process in the Andes, which is studied in the Conga case study. Then, we would see the inputs flows coming from the Andean mountains in Cajamarca. They are the primary production of grazing land and water flows that are transformed into output flows of fresh milk by the cows, which also produce output flows of greenhouse gases of methane. This milk production process is possible due to the funds of human activity of Andean farmers – called *campesinos* – who use their funds of land and cows to transform the inputs into outputs flows. On other side of the supply chain, we can observe the production of packaging materials in a factory in China, which implies the inputs flows of raw metals and the outputs flows of tinplate sheets and wastes. And, perhaps some of these raw metals were extracted from mines located in Peru – considering that China is the main minerals importer – which is also related to ecological distribution conflicts with *campesinos* living at the commodity frontiers in the Andes.

Methodology

The argumentation of this thesis is based on the flow/fund theory of economic production developed by Georgescu-Roegen (1971), which is used to study ecological distribution conflicts. The thesis develops an empirical methodological contribution that combines two approaches: (1) the environmental valuation triadics approach created by Farrell (2007), which characterizes the systems of value articulation of the respective social actors; and (2) the multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM) created by Giampietro and Mayumi (2000a, 2000b, 2009), which is an extension of the flow/fund model. It is a procedure to combine attention to purpose and process, in the application of the flow/fund theory.

The rationality behind this empirical methodology contribution is based on the study of Georgescu-Roegen's theory made by Farrell and Mayumi (2009), which considers the flow/fund model a general theory of economic production where *time* and *tradition* are the basis for understanding the nature of the boundaries of the economic process we have in mind. The boundaries of a specified economic process include: (1) the *frontier*, which sets the process against its "environment"; and (2) the *duration*, which sets the time moments at which the analytical process we have in mind begins and ends (Georgescu-Roegen, 1971: 213). Farrell and Mayumi's metaphor of *cuisine* illustrates the idea: "Differences between cuisines reflect not only different ingredients but also the application of different sets of tradition, in the form of different recipes …[which] include instructions regarding how the ingredients are to be combined …" (Farrell and Mayumi, 2009: 303). For instance, a set of ingredients consisting of fish, lemons, *ají*, salt, onions, tomatoes, and cilantro can be used to prepare a *ceviche*, that is, the fish with some salt cooked during 15 minutes with lemons juice plus ají and chopped onions, then, with some tomatoes and cilantro as secondary complements. Alternatively, the same ingredients can be used to prepare a *pescado sudado*, that is, the fish plus chopped tomatoes and onions, plus ají, salt, and cilantro, which are cooked during 10 minutes with heat in a covered pot, then, adding some lemon juice over the cooked fish to taste. However, the special recipe for a *ceviche* or *pescado sudado* depends on the traditions of the particular coastal regions and families living in Peru.

Complementary, the metaphor of the *apple tree* developed by Katharine Farrell is useful for understanding the relation of this theory with the analysis of environmental conflicts: Let us imagine a carpenter and a farmer observing the same tree. The frontiers of their respective economic processes are the same: the tree and its immediate environment. But, the duration of the economic process of interest to the carpenter, i.e., that associated with the purpose of extracting timber, is the time required for cutting the tree (e.g. some hours), while for the farmer, it is the productive life of the tree (e.g. many years). Then, the carpenter visualizes the tree as an input *flow* of the production process of making tables, whereas the farmer is thinking of the tree as a *fund* required to transform input flows of nutrients, water, and solar energy into output flows of apples.

Therefore, following Farrell and Mayumi (2009) and based on the flow/fund theory of Georgescu-Roegen (1971), the boundaries of the economic process depend on its *purpose*, which in addition are related to the visualizations and perspectives of the specific social actor (i.e. their particular *cuisine*). For instance, two social actors with different economic purposes and located in the same environment (e.g. some land, river, lake, mountain, or forest) can have a conflict on its identity, which may be, to them, either a flow or fund. The social actor visualizing this "environment" as a *flow* will make efforts toward its qualitative transformation into a product. And, the social actor visualizing the same "environment" as a *fund* will make efforts for its maintenance and conservation over time. It is argued in the present thesis that this can be understood as part of the nature of an ecological distribution conflict at the commodity frontiers, where local social actors, mainly indigenous people and traditional farmers, have to defend the integrity of their funds against external social actors, mainly private corporations, that visualize these environments as input flows, with the determination to transform them into commodities required by modern industrial societies, leaving behind their respective material wastes, another output flow, that become environmental liabilities or ecological debts (e.g. the tailings and waste rocks of mines, the agrochemicals dispersed in water systems, and the accumulation of greenhouse gases in the atmosphere and other carbon sinks).

MuSIASEM

The Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM) approach, which was first introduced by Giampietro and Mayumi (2000a, 2000b), and then further developed by Giampietro (2003), Giampietro and Mayumi (2009), Giampietro et al. (2009), and Giampietro and Bukkens (2015), integrates three theoretical concepts: (1) far-from equilibrium thermodynamics, as applied to ecological analysis; (2) complex systems theory; and (3) bioeconomics, that is, the flow/fund theory of economic production. Giampietro and Bukkens (2015: 19) describe this approach as follows: "MuSIASEM is a transdisciplinary approach to sustainability assessment that integrates quantitative information generated by distinct types of conventional models based on different dimensions and scales of analysis." MuSIASEM is used here for the multi-scale quantitative representation of flows, funds, and ratios (i.e. flow/fund, fund shares, flow shares) of specific economic processes, which are related to the visualizations and perspectives (or systems of value articulation) of their respective social actors. MuSIASEM is used in different ways (i.e. different purposes and methodological applications) in the three case studies (i.e. Camisea, Conga, and Sierra del Divisor).

The case study of Camisea has the purpose to understand the energetic metabolism of the mining sector in relation to the limited stock of Camisea natural gas (the main fossil fuels reserve of Peru by far) and the energy demands of the rest of society. The research question is: What are the long-term national energy system implications of the recent government supported growth of the mining sector? Then, the *fund* of human activity is considered across multiple scales, from the national scale to specific economic sectors, and juxtaposed against their respective *flows* of exosomatic (outside the body) energy: more specifically, *flows* of electricity. Key indicators are calculated, which include the flow/fund ratio in MJ of electricity per hour of human activity in the mining sector and other economic sectors, and the flow share of total electricity allocated to the mining sector. This information facilitates comparisons between the mining sector and other economic sectors (e.g. the building and manufacturing sector), providing an empirical basis for judging the implications of projections of future energy demand in Peru, taking into account the new capital investments in the mining sector, supported by the national government. Also, the Camisea case study is related to the energy-water-mining complex, which is studied by Parker et al. (2015) in South America and Sharife and Bond (2011) in South Africa. For instance, Parker and colleagues (2015) begin their research work with the fact that the mining sector uses large quantities of energy and water and is one of the most widespread productive activities (extractive more precisely) in the region. It is supported by the results of the MuSIASEM applied to this case study, which indicates that the mining sector uses 62 MJ of electricity per hour of human activity, which represents

11 times the electricity used per hour of human activity in the building and manufacturing sector; and the electricity used by the mining sector (29 PJ in 2010) was higher than the electricity used by all households in Peru (27 PJ in 2010), representing a flow share of 25% of total electricity used in the country.

The case study of Conga and the gold mine conflict in the Andes applies the MuSIASEM for the analytical representation of the minerals extraction process of the mining company (i.e. Yanacocha) and the milk production process of *campesinos* (Andean small holder farmers), in order to explore the anatomy of this ecological distribution conflict. Firstly, the Ricardian land element, measured in square kilometers of area, is a fund for both the mining company and the *campesinos*. Then, the concept of *land materials* is introduced, which is, the volume of land (or mountain) that comprised of the soil, surface water, aquifers, and rocks extracted during the mining process, measured in millions tons of weight. This land materials element of the production process complements the indestructible *fund* element of Ricardian land; whereas Ricardian land is always a *fund*, land materials can be either a *fund* or *flow*, depending on the visualization, perspective, and purpose of the social actors in conflict at the commodity frontier of the Conga Mountain. For Yanacocha (i.e. Newmont Mining Corporation, Buenaventura, and the International Finance Corporation of the World Bank) these land materials are input flows to be transformed into output flows of copper-gold concentrates and wastes; for the *campesinos* in Cajamarca the same land materials are funds to be maintained or conserved for the agricultural process, which is an ecological-economic value that is complemented with the rest of social, political, and cultural values of these local communities living in the Andes. Then, what it is show here, is that the social conflicts occurs in a pre-analytical level, it means in the definition of the boundaries of the economic process, which depends on purpose and ultimately in the perspectives and visualizations of different social actors.

The case study of Sierra del Divisor and the proposed transcontinental railway in Amazonia applies the MuSIASEM in a simplified way in order to describe key economic processes in two periods of time, before and after the construction of the Transcontinental Brazil-Peru, Atlantic-Pacific railway (FETAB, in Spanish) that would cross the Sierra del Divisor tropical rainforest, representing a major change in the boundary conditions of the observed system (DAR, 2016). The economic processes studied in this case include: industrial soybean production in Brazil, alluvial gold mining extraction in Peru, fishing by native communities, rice production by small farmers, and hunting and gathering activities of indigenous people living in voluntary isolation. This application of MuSIASEM is used to develop an initial quantitative baseline analysis of existing economic processes, for which scenarios of change are then developed in order to project the potential consequences of the railway project for the sustainability of local communities in the Sierra del Divisor. For example, based on that analysis, we can see that the economic process of hunting and gathering of the Isconahuas indigenous people requires the *funds* of a significant land area of Amazon rainforest (i.e. 275,000 hectares) as well as adults' human activity time, in order to hunt and gather enough *flows* of food for their people. However, after the construction of the railway new external pressures (e.g. timber extraction, soybean production, illegal mining) may well drastically reduce, the land area available for hunting and gathering. The human activity time allocated to hunting and gathering would have to increase radically in order to maintain the same *flows* of food for their people. Perhaps, this new allocation of adults' human time can imply a reduction on the adults' human time allocated to the education of children (e.g. how to hunt animals and how to gather plants in the forest), which is critical for the subsistence of the next generation of Isconahuas.

Environmental valuation triadics

The *environmental valuation triadics* concept was created by Farrell (2007) to explore features of the environmental valuation process through a co-evolutionary approach to the relationship between values and valuation. "Based on established works concerning complexity, living systems, and social, economic, evolutionary and hierarchy theories, it is argued that a special form of recursive co-evolution takes place between articulated values and methods of value articulation, within the environmental valuation system" (Farrell 2007: 14). The concept depends on two underlying presumptions: (1) that the process of value articulation can be described as a triadic hierarchical system (Salthe, 1985; Mayumi, 2001), and (2) that all articulations, or expressions, of environmental value are embedded within social and institutional contexts that influence how objects of valuation are perceived. Then, an environmental valuation triadic can be understood as a complex representation of the process of value articulation (Farrell and Vatn, 2004; Vatn, 2005; Farrell, 2009[2005], 2007) comprised of three hierarchical levels: (1) higher (structure – value system), (2) focal (focus – perception of the object of valuation), and (3) lower (functions – articulated values) (Farrell, 2007). The focal level is the central part of the valuation triadic and reflects the way in which a social actor, or group of social actors, perceives the object of valuation. In the present thesis, the object of valuation is related to a natural system (e.g. land, mountain, river, lake, forest), which is part of an ecological distribution conflict.

In simple terms, the *environmental valuation triadics* approach applied to the study of ecological distribution conflicts at the commodity frontiers of Peru can be explained using the slogan from the Conga gold mine conflict and elsewhere in Latin America: "el agua vale más que el oro" (the water is worth more than gold). As this regards, "vale más" means that water is a priority over gold in terms of a mix of cultural, political, ecological, social, and economic values that are different from monetary values or market exchange values. For instance: it is not possible to produce food for humans and animals without water; an artificial water reservoir is not the same as a natural water system of lakes, rivers, and aquifers; it is not possible to trade a sacred lake (a mother)[4], no matter what the price. This slogan, "el agua vale más que el oro", is said mainly by *campesinos* defending their mountains (land and water) against the increasing number of mining corporations and projects in the Andes. For the example – "el agua vale más que el oro" – we can build the respective environmental valuation triadics as follows: (1) the structural level (or the framing) is represented by the *living well* perspective of the campesinos in the Andes, that is, *el buen vivir* in Spanish or the *sumaq kawsay* in Quechua, complemented by a history of environmental damage (liabilities)[5] and social conflicts due to minerals extraction in the region; (2) the focal level is represented by the mountain (i.e. the *land materials* of rocks, land, and water), the focus of conflict between the *campesinos* and the mining corporations. In the present thesis the focus can be understood as the point of the conflicts between economic processes (e.g. fresh milk production from natural pastures versus open pit gold and copper extraction); and (3) the functional level is the manifestation of the mix of cultural, political, ecological, social, and economic values (or articulated values or expressions) different than monetary values used by the *campesinos*. In the present thesis are the flows and funds, which are the manifestations of their respective economic process – that is, "el agua vale más que el oro"; the mountain is the source of water; the mountain is a *fund*.

The rest of the document is organized as follows: Chapter II presents the case study of Camisea and the national energy-water-mining complex. Then, Chapter III analyzes the case study of Conga and the gold mine conflict in the Andes. And, Chapter IV describes the case study of Sierra del Divisor and the transcontinental railway in the Amazonia. Finally, Chapter V summarizes the main thesis contributions and conclusions, and some recommendations for future research.

[4] The movie "Daughter of the Lake" (Hija de la laguna) (2015) directed by Ernesto Cabellos Damián describes this sacred values in the Andes (http://www.daughterofthelake.pe/). The synopsis is as follows: "At the height of the Peruvian gold rush, Nelida, an Andean woman able to communicate with water spirits, uses her powers to prevent a mining corporation from destroying the body of water she considers her mother. A gold deposit valued at billions of dollars lies just beneath Nelida's lakes and leads farmers and Latin America's biggest gold producer into conflict."

[5] For instance, the inventory 2015 of Mining Environmental Liabilities in Peru reported by the Ministry of Energy and Mining (MINEM) accounts a total of 8,616 sites (http://sinia.minam.gob.pe/normas/actualizan-inventario-inicial-pasivos-ambientales-mineros).

Chapter II

A metabolic profile of Peru: An application of Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM) to the mining sector's exosomatic energy flows[6]

Jose Carlos Silva Macher

The present Peru's metabolic profile study poses the specific question: what are the long-term national energy system implications of the recent government supported growth of the mining sector? The question is addressed by analyzing interactions between human economic activity (in hours) and electricity input flows (in joules) in the mining sector of the Peruvian economy in 2000 and 2010, with a projection for 2020. The methodology is based on the Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM), which is an application of Georgescu-Roegen's bioeconomics approach. Empirical results found for the national economy show: (a) the massive increase in size of the energy system, which is explained by exploitation of the Camisea natural gas reserves; and (b) the potential for establishing a carbon lock-in in the electricity sector, due to increasing construction of electricity plants based on natural gas as their primary energy source. Empirical results specific to the mining sector indicate: (a) the extremely high electricity metabolic rate (eEMR) of the mining sector (61.6 MJ/h in 2010), which was found to be 11 times the rate of electricity used per hour of human activity in the building and manufacturing sector in Peru; and (b) the potential increases in the proportion of electricity used in the mining sector (flow share), which could jeopardize the availability of high quality primary energy supplies for the rest of society. In light of these implications, it is argued that the Peruvian government's strong support for growth of the mining sector may have to be reconsidered.

Introduction

The metaphor of social metabolism can be understood as "the basic idea that the economy is physically embedded into the environment, i.e. the economy is an open system with regard to matter and energy" (Schandl et al. 2002, 5). For an overview of the evolution of the concept, see Martinez-Alier (1987). The concept of social metabolism, invites us to develop analytical representations of economic processes in relation to their contexts (i.e., the environment and/or other economic processes), which can be useful for

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dealing with critical sustainability issues, ranging from climate change to scarce availability of natural resources, pollution prevention, carbon lock-in, technological innovation, and ecological distribution conflicts. The study presented here, concerning changes in the Peruvian energy and mining sectors, between 2000 and 2010, is intended to contribute toward a growing body of industrial ecology literature on material use across world regions (Weisz and Schandl 2008) by adding a further national economy study that gives special attention to mineral exports (see, for example, Schandl et al. 2008 for Australia; Russi et al. 2008 for Chile, Ecuador, Mexico and Peru; Vallejo et al. 2011 for Colombia; and Singh et al. 2012 for India).

Complementing data presented in Russi et al. (2008), this study poses the specific question: what are the long-term national energy system implications of the recent government supported growth of the mining sector in Peru? The question is addressed by analyzing interactions between human economic activity and energy input flows in the mining sector of the Peruvian economy in 2000 and 2010, with the results then used to inform predictions about potential further developments, leading up to 2020. While this offers only a partial analytical representation of Peru's metabolic profile, the tight focus allows for a critical assessment of present national government policy, which strongly supports growth of the mining sector (MEF 2013; MINEM 2012). This highlights, for example, risks associated with increasing natural gas derived electricity dependence in the mining sector, which could have serious medium term implications for the Peruvian economy, due to the limited stock of natural gas available within the country. In order to answer this research question, a Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM) approach is used. In this way the Peruvian economy is represented analytically across scales, from the national economy to the mining sector, integrating representations of funds of human activity and flows of energy within an environmental context.

Bioeconomics: the flow/fund model

The theoretical background for the present case study is based on the flow/fund model. Following Georgescu-Roegen (1971), an economic process, which operates within specific spatial and temporal boundaries, can be represented by a combination of flow and fund elements, where funds (e.g., Ricardian land, capital proper and human activity) transform input flows (from nature and from other processes) into output flows (e.g., product and wastes). The spatial boundary may be understood as a frontier, delineating the relationship between the economic process and its physical environment, while the temporal boundary may be understood as duration, delimiting when the economic process we have in mind begins, and when it ends. Together, they define each element's identity as either a flow or a fund: based on whether the element, which appears within the physical boundaries of the economic process, is consumed, produced or remains unchanged over the duration of that process. Georgescu-Roegen (1971) points out that what counts as the boundaries of an economic process depends upon the purposes and values served by that process. Farrell and Mayumi (2009), in bringing attention to this, propose that the flow/fund model can be understood as a general theory of economic production, which takes into account the relationship between time, production and tradition, arguing: (a) that the flow/fund model is designed to be employed in conjunction with attention to how the boundaries of a given process are determined; and, (b) that process boundaries are dialectical distinctions – between process and not-process – which are strongly related to both time and tradition. For instance, in a case study of the Conga gold mine in northern Peru, Silva-Macher and Farrell (2014) employ the flow/fund model to analyze an ecological distribution conflict between Newmont mining company and local Andean peasants (campesinos), casting the conflict in terms of the contested flow/fund statuses of the elements water and land. The element identity of the Conga Mountain, both the land itself and the aquifers below, is that of a fund from the perspective of the campesinos, due to its function in the milk production process, slowly transforming the input flows of solar energy, water, and nutrients into the output flows of pasture for cattle and eventually milk. From the perspective of the mining company, Conga Mountain is a flow element, with the input flow of extracted materials being transformed during the mining process, using the fund elements mining equipment and human activity, into the target output flows of gold and copper concentrates and the residual output flows of inert and contaminated wastes. Understood in this way, the flow/fund model is used here to explore how the energy and mining sectors in Peru are related to each other, not only in physical but also in conceptual terms, as reflected in government policies, which influence the structure of economic processes in the country.

The present article is structured as follows. First, it is provided the logic of MuSIASEM and the analytical materials to be used below. Second, it is described the economy-environment relationships used here to represent Peru's social metabolism in the mining sector. Next, it is summarized the empirical results for 2000 and 2010. Key results are discussed, in terms of changes, over the study period, in energy throughput across selected sectors of the Peruvian economy, including changes in electricity flow into the mining sector, which are then extrapolated for the year 2020, based on government targets for growth in that sector over the next decade. The final section reviews the long-term implications of these results for the structure of the national energy system and provides some recommendations for further research on the topic.

Materials and methods

Study of the social metabolism in the energy system of a national economy requires analytical representation of both external constraints, such as the availability of resources for the economy (e.g., of natural gas) and internal constraints, including their technological state and institutional organization (e.g., government support for, and electricity supply and demand within the mining sector). In addition, such analysis needs to take into account interactions between and across scales, as energy use is not evenly distributed among economic sectors. This is particularly important in the present study, which is looking for medium and long-term structural changes in the energy system at the national level that may arise as a result of radical changes in the mining sector. Although, the data used here is drawn from official government agency reports (MEF 2013; MINEM 2011, 2012), these reports generally lack economy/environment integrated analysis. Analyzing these data using MuSIASEM takes into account how current policy is affecting social metabolic patterns over the medium- and potentially also the long term.

Multi-scale integrated analysis of societal and ecosystems metabolism (MuSIASEM)

MuSIASEM, which was first introduced by Giampietro and Mayumi (2000 a, b), and then further developed by Giampietro (2003), Giampietro and Mayumi (2009), and Giampietro et al. (2009), integrates three theoretical concepts: (a) far-from-equilibrium thermodynamics, as applied to ecological analysis, (b) complex system theory, and (c) bioeconomics (i.e., the flow/fund model). For an overview of these concepts and a general introduction to how the method is applied to study of a national economy see Ramos-Martin et al. (2007). For the purpose of explaining how the method has been applied here, it is important to note that the national economy is analyzed across multiple scales, starting with societal averages and total values (level n) and moving down, to specific sectors (level n-1) and sub-sectors (levels n-2, n-3, etc.), all of which are presumed to be embedded within an external environmental context (level n+1). Once the scales are specified for a given study, then logically compatible pairs of fund/flow elements are selected in order to build a representation of the economic processes in question. A pair of fund/flow elements is compatible with relation to a process. For example, a compatible pair is fresh milk (an input flow) and the pasteurizer equipment (a fund) that transforms this ingredient into pasteurized milk (an output flow) in a dairy products factory. An incompatible pair would be fresh milk (an input flow) and packaging materials (another input flow) because packaging materials do not transform fresh milk into pasteurized milk. The present study uses data for the fund element human activity (reported in hours), the input flow element exosomatic (i.e., outside the body, such as gas or wood based) energy (reported in joules), and the output flow element added economic value (reported in dollars), all of which are represented as a combination of level-specific absolute values (extensive variables) and inter- and intra-level relational values (intensive variables). Source data and calculations are summarized in Table 1.

Table 1: Key extensive and intensive variables used in the MuSIASEM

Indicators	Symbol	Unit	Calculation
Extensive variables			
Total human activity	THA	Gh	Population*24h*365
Human activity in paid work sector	HA_{PW}	Gh	ILOSTAT data [1]
Human activity in household sector	HA_{HH}	Gh	HA_{HH} = THA - HA_{PW}
Total energy throughput	TET	PJ	Total primary energy supply
Energy use in paid work sector	ET_{PW}	PJ	ET_{PW} = TET - ET_{HH}
Energy use in household sector	ET_{HH}	PJ	IEA data
Gross Value Added	VA	US$	UN data
Intensive variables			
Energy metabolic rate, societal average	EMR_{SA}	MJ/h	EMR_{SA} = TET / THA
Energy metabolic rate, paid work sector	EMR_{PW}	MJ/h	EMR_{PW} = ET_{PW} / HA_{PW}
Fund share n-1/n, in the paid work sector	-	-	HA_{PW} / THA
Flow share n-1/n, in the paid work sector	-	-	ET_{PW} / TET
Economic labor productivity, societal average	ELP_{SA}	US$/h	ELP_{SA} = GDP / THA
Economic labor productivity, paid work sector	ELP_{PW}	US$/h	ELP_{PW} = GDP / HA_{PW}

Source: Giampietro and Mayumi (2009); Ramos-Martin et al. (2007)

[1] The human activity allocated to the paid work sector is calculated as follows: (employment by economic activity)*(mean weekly hours actually worked per employed person by economic activity)*(365/7 weeks per year); based on the ILO definitions (www.ilo.org/ilostat).

Materials

This study is based on secondary data collected from a range of sources, including: the United Nations Population Division (UNPD) for total population and distribution by age group; the International Labor Organization (ILO), both ILOSTAT and LABORSTA databases, for the distribution of employment across economic sectors and respective average weekly working hours; the International Energy Agency (IEA) for energy throughput flow data, expressed in tons of oil equivalent (toe) based on net calorific values, which are disaggregated according to both energy carrier type and economic sector; and the United Nations National Accounts database (UN data) statistics on economic added value. These data are complemented with and have been cross-checked against national sources:

specifically, Peruvian Ministry of Energy and Mining (MINEM) reports and the National Institute of Statistics and Information (INEI).

Theory and calculations

Pre-analytical step

The study presented here focuses on relationships between the whole economy of Peru, the mining sector and the energy sector. The territory of the country delimits the main spatial boundary for study, with the national economy taken as the focal level of analysis, labeled level n in Figure 1. Level n-1 is disaggregated into the household (HH) and the paid-work sector (PW), and the paid-work sector is then further disaggregated, at level n-2 into the agriculture (AG), industrial (PS), and services and government (SG) sectors, following the standard classification for countries in such studies (Eisenmenger et al. 2007, Ramos-Martin et al. 2007, Giampietro et al. 2009, Recalde and Ramos-Martin 2012). Finally, for the purposes of the present study, the industrial or productive sector (PS) is further disaggregated, at level n-3, in order to analyze relationships between: the mining (MH), building and manufacturing (BM), and energy (ES) sectors, the paid-work sector (PW) and the national economy as a whole. This is an expansion of the standard classification, specifically designed for the study of mineral resource rich countries specialized in primary exports. The 10-year period between 2000 and 2010 delimits the temporal boundaries of the empirical study, reflecting Peru's current democratic era of elected governments, which followed the 1990s' structural reforms, based on the Washington consensus. This is then complemented with rough estimates for energy and material flow throughputs in the mining sector for the year 2020, assuming government growth targets are achieved.

Functions of the economic sectors

In order to understand the systemic behavior of the economy, the proposed economic structure for Peru's metabolic profile is related to a set of functions, which include: the reproduction of humans in the household sector, the production of food in the agriculture sector, the production of products in the building and manufacturing sector, the production of services in the services and government sector, and the production of energy carriers in the energy sector (Giampietro and Mayumi 2009). However, in order to understand the particular case of Peru, one must also include the function 'extraction of minerals' in the mining sector, which is responsible for putting minerals into flow, representing 11% of national added value in 2010 (INEI 2015). Output flows from the mining sector may be inputs flows for the industrial sector of the national economy, where they are transformed into new output flows, for example, in the building and manufacturing and the energy sectors, or they may be exported. Since, in Peru, the majority of these minerals are exported, this sector can also be understood to serve a key function in the social metabolism of the global economy – level n+1 – however exploration of that topic is beyond the scope of the present study.

Results and discussion

The empirical results, based on targeted application of the MuSIASEM methodology and the pre-analytic criteria outlined above, are summarized in Tables 2 and 3. The indicators, which are compared with reference values for Spain, Brazil, and Chile, include both, extensive variables related to the size of the economy; and intensive variables concerning relationships within the economy. Following presentation of this context, the relationship between energy flows in the mining and energy sectors of Peru is reviewed in detail. An overall picture of Peru's metabolic profile is presented in Figure 1.

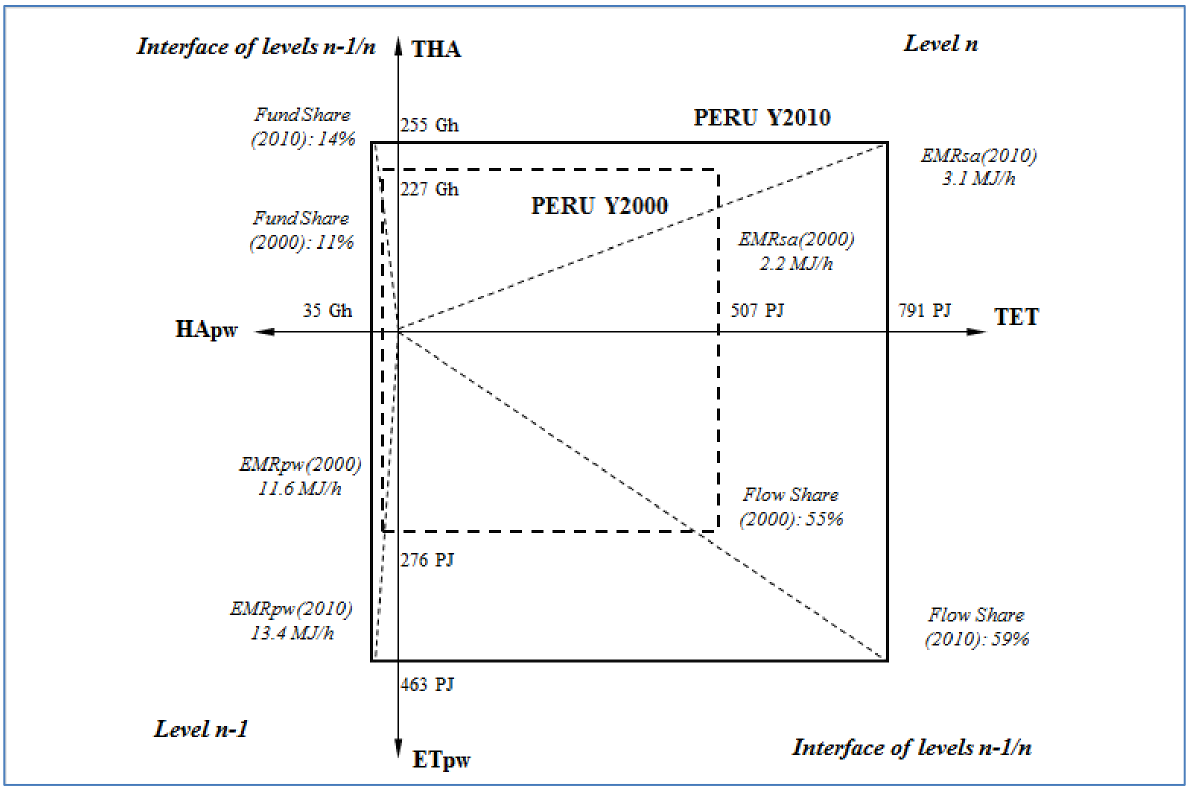


Figure 1: Flow-Fund representation of MuSIASEM: Peru years 2000 and 2010. Source: Own elaboration based on Giampietro and Mayumi (2009).

Extensive variables

At level n, from 2000 to 2010, general increases can be observed for human activity, energy use, and added value (see Table 2 and Figure 1). In the paid work sector (HA_{PW} and

ET_{PW}), which provides the reference data for level n-1, a 45% increase in human activity can be seen to reflect not only simple population growth, which would be expected to leave the Fund Share value unchanged, but also a combination of other factors, including increased overall employment, formalization of the economy, shifting demographic structure, and more participation of women in the work force, as reported by OIT (2011). By contrast, in both periods, roughly 60% of HA_{PW} is associated with the services and government sector (HA_{SG}). However, average economic labor productivity in the service and government sector, which is an indicator of the types of employment in and capitalization structure of an economy, is very low in Peru, with only 2.66 US$/h in 2010, (see Table 3), as compared with reference values for Spain and even in comparison with Brazil and Chile.

Table 2: Extensive variables: the size of the economy

	Symbol	Level	Peru Y2000	Peru Y2010	Variation
Human activity in Gigahours					
Total human activity	THA	n	226.55	254.71	12%
HA in household sector	HA_{HH}	n-1	202.73	220.08	9%
HA in paid work sector	HA_{PW}	n-1	23.82	34.63	45%
HA in agriculture sector	HA_{AG}	n-2	4.73	7.52	59%
HA in services and government sector	HA_{SG}	n-2	15.04	20.66	37%
HA in industrial sector	HA_{PS}	n-2	4.06	6.45	59%
HA in mining sector	HA_{MH}	n-3	0.24	0.47	98%
HA in building and manufacturing	HA_{BM}	n-3	3.71	5.85	58%
HA in energy sector	HA_{ES}	n-3	0.11	0.13	23%
Energy use in Petajoules					
Total energy throughput	TET	n	506.60	790.55	56%
ET in household sector	ET_{HH}	n-1	230.28	327.37	42%
ET in paid work sector	ET_{PW}	n-1	276.32	463.18	68%
ET in agriculture sector	ET_{AG}	n-2	26.50	17.31	-35%
ET in services and government	ET_{SG}	n-2	83.74	174.30	108%
ET in industrial sector	ET_{PS}	n-2	166.07	271.57	64%
ET in mining sector	ET_{MH}	n-3	53.42	59.57	12%
ET in building and manufacturing sector	ET_{BM}	n-3	83.33	132.18	59%
ET in energy sector	ET_{ES}	n-3	29.33	79.81	172%
Gross value added in constant billion US dollars of 2005					
AV in paid work sectors	AV_{PW}	n-1	61.33	96.20	57%
AV in agriculture sector	AV_{AG}	n-2	5.21	6.51	25%
AV in services and government sector	AV_{SG}	n-2	18.33	34.66	89%
AV in industrial sector	AV_{PS}	n-2	37.78	55.03	46%
AV in mining sector	AV_{MH}	n-3	3.50	10.99	214%
AV in building and manufacturing sector	AV_{BM}	n-3	13.29	21.84	64%
AV in energy sector	AV_{ES}	n-3	1.54	1.83	19%

Source: UNDP (2011), ILOSTAT (2013), and LABORSTA (2013) for human activity; IEA (2013) and MINEM (2011) for energy; and UN Data (2015) and INEI (2015) for added value.

The energy indicators (ET values in Table 2) include two anomalies that need to be specifically addressed, before proceeding. At level n-2, a decrease of 35% in the energy throughput associated with the agriculture sector (ET_{AG}), is explained by a fishery collapse during the intervening period, which saw radical reductions in domestic fishing activities, a major component of Peru's agricultural sector, with extraction falling from 10.7 million tons in 2000 – mainly anchovy for fishmeal production – to 4.3 million tons in 2010 (FAOSTAT 2013). Also at level n-2, a 108% increase in energy throughput associated with the services and government sector (ET_{SG}) can be attributed largely to massive expansion in the transportation and commercial sectors during the intervening period, which was facilitated by construction of new infrastructure (i.e. roads and buildings). Within the industrial sector (ET_{PS}), changes in the energy throughput associated with the mining and energy sectors are the points of focus for the present study. Here, at the level n-3 the acute interdependence of the mining and energy sectors in Peru can be clearly observed. First, while an increase of only 12% in the mining sector (ET_{MH}) might give the impression that not much is happening on this front, this relatively stable value for throughput in tonnes of oil equivalent is associated with a change in how the electricity used in this sector is being generated: from use of low efficiency, oil powered generators, employed on-site, inside the extractive industries; to use of higher efficiency gas powered electricity generating plants, located inside the energy sector. Second, the radical increase of 172% in the energy throughput in the energy sector (ET_{ES}) over the study period is due both to the expansion of electricity generation and to a new energy use, the refinement of hydrocarbons extracted in the Camisea natural gas project, which started operations in 2004.

Finally, with regard to the added value, the increase of 57% in standardized dollars per hour at the level n-1, is explained by a combination of effective market focused macroeconomic policies, including infrastructure investment (reflected by the 64% increase in AV_{BM}, at level n-3), with increased private investment (e.g., in the mining sector AV_{MH}, with a 214% radical increase) and favorable terms of trade for metal ore sales, complemented by some improvements at the microeconomic level, in terms of productivity, less informal economic activity, improved human capital and increased use of technological innovation (MEF 2013). However, this increase is also related to the introduction of new high quality primary energy from the Camisea gas project. Using MuSIASEM to disaggregate the national data in this way, it is possible to anticipate two potential problems associated with this pattern of growth: (a) the temporary character of local natural gas availability means that this economic growth is not self-sustaining, so new, perhaps imported flows will be needed, eventually; (b) there is a good chance that this type of economic growth will lead to carbon lock-in in the area of electricity generation, which would increase incentives to pursue further hydrocarbons exploitation in Amazonia and to develop Peru's next best alternative for electricity generation, through expansion of hydroelectric projects. These points are discussed further below.

Intensive variables

Peru is an economy with a low energy metabolic rate (EMR) at the societal average (3.10 MJ/h in 2010), as compared with Spain (12.30 MJ/h), and a very low one when compared with the average for Australia, the United States and Canada (38.8 MJ/h) (Ramos-Martin et al. 2007). This can be partially explained by the allocation of human activity, with the majority of labor hours based in traditional agriculture and small-scale commercial activities with low level of capitalization. In 2010, 81% of the hours spent engaged in paid work in Peru were either in the agriculture (AG) or the services and government (SG) sectors, both of which have relatively low exosomatic energy use rates (see Table 3). The rest of the paid work sector is concentrated in extractive industries (MH) and building and manufacturing (BM), as part of an industrial sector that also has a relatively low EMR, which can be partially explained due to its low added value contribution along the supply chains. As regards consumption patterns (i.e. exosomatic energy throughput in the household sector), while it is outside the scope of the present study to develop a detailed analysis of differences between rural and urban consumption patterns and across social groups in Peru, due to extreme income disparity it can be assumed that the overall household sector EMR of 1.49 MJ/h of human activity is well above the consumption rate of most households, as some urban households in coastal regions are likely to have EMRs equivalent to those in industrialized countries, with the majority of the population, in particular rural households in the Andes and Amazonia having extremely low EMRs.

Peru's comparatively low EMR in the agriculture sector (2.3 MJ/h, as compared with Spain's 50.0 MJ/h) can be explained, in part, by topography, as horizontal (or plains) agriculture with high capitalization – typical of more industrialized countries – is much more exosomatic energy intensive than the vertical agriculture typical of the Andes/Amazon regions in Peru, which has low capitalization and high human (or endosomatic) energy intensity. Where industrialized plains agriculture relies on exosomatic energy flows to move water with pumps, soil with tractors, and to run sprayers, harvesters, conveyers, and trucks, Andean agriculture relies mainly on the human activity of campesinos (peasants) with a minimum of exosomatic (outside the body) devices, some of which, such as draught animals, feed on natural pastures instead of the fuel used to run tractors and trucks. As a proxy, the values of EMR in the agriculture sector of reflect these kinds of differences in the two food production systems.

Table 3: Intensive variables: intrinsic features of the economy

	Level	Peru Y2000	Peru Y2010	Spain Y1999	Brazil Y2000	Chile Y2000
Exosomatic Metabolic Rate in MJ/h						
EMR societal average	n	2.24	3.10	12.30	5.21	7.60
EMR in paid work sector	n-1	11.60	13.38	137.70	38.78	58.34
EMR in household sector	n-1	1.14	1.49	3.30	1.41	2.64
EMR in agriculture sector	n-2	5.61	2.30	50.00	9.82	4.67
EMR in industrial sector	n-2	40.95	42.10	330.00	139.08	192.13
EMR in services and government sector	n-2	5.57	8.44	56.00	15.12	20.45
Fund Share / Flow Share in %						
Fund share of HA in paid work sector	n-1/n	10.5%	13.6%	7.0%	10.2%	9.0%
Fund share of HA in household sector	n-1/n	89.5%	86.4%	93.0%	89.8%	91.0%
Flow share of ET in paid work sector	n-1/n	54.5%	58.6%	76.0%	75.6%	68.3%
Flow share of ET in household sector	n-1/n	45.5%	41.4%	24.0%	24.4%	31.7%
Economic Labor Productivity in US$/h						
ELP societal average	n	0.27	0.38	2.48	0.44	0.70
ELP in paid work sector	n-1	2.57	2.78	35.77	4.34	7.81
ELP in agriculture sector	n-2	1.10	0.87	19.40	1.46	3.51
ELP in industrial sector	n-2	4.52	5.37	42.24	5.89	11.03
ELP in services and government sector	n-2	2.51	2.66	36.60	4.36	6.70

Source: Own elaboration for Peru; Eisenmenger et al. (2007) for Brazil and Chile; Giampietro and Mayumi (2009) for Spain; and UN Data (2015) for standardized added value in all countries.

Mining sector's energy flows

The mining sector is one of the main users of energy in Peru, using both oil and electricity. In addition, it is also a key supplier of primary energy to the energy sector, as the extraction of crude oil and natural gas (Figure 2) is a mining activity. As mentioned above, between 2000 and 2010 the mining sector of Peru has changed the energy carrier used to produce electricity, from oil to natural gas. Also, it has moved the transformation into electricity from the mine to power plants. This relationship, which reflect wide availability of natural gas for electricity generation, and which has been supported by government policy, is represented below in Figure 3. Moreover, the mining sector extracts natural gas, which he energy sector then transforms into energy carriers (i.e., electricity and fuels), which are then used by the mining sector to extract, transform and export metal ores to generate economic added value.

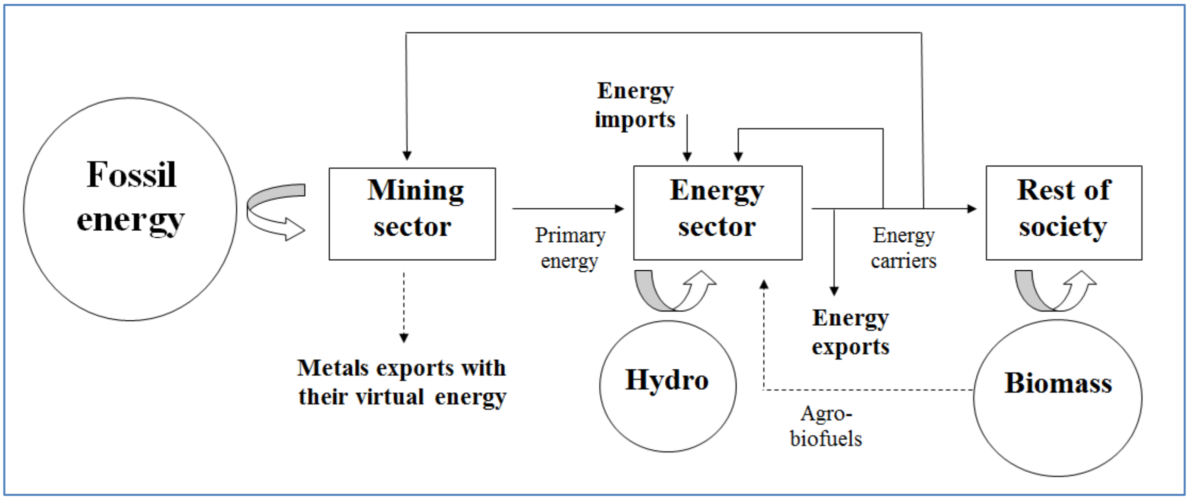


Figure 2: Interdependent energy flows in the mining and energy sectors. Source: Own elaboration based in Giampietro and Mayumi (2009); IEA (2013); MINEM (2011).

According to MINEM (2012), the monetary value of metal exports from Peru was 21.7 billion US$ in 2010, which represented 60% of the country's total exports. The predominance of this export oriented mining sector is a key characteristic of Peru as a provider of raw materials for the global economy, which has been reinforced by increasing mining investments over the last decade. Mining investments are strongly promoted by the Peruvian Government (MEF 2013) and plans for new investments include a total of 47 key mining projects to be initiated between 2012 and 2017, with a predicted value of 53.7 billion US$ (MINEM 2012). This means that the cumulative value of 15 billion US$ of mining investment between 2001 and 2010 is expected to be quadrupled, reaching a total of roughly 60 billion US$ over the two decades.

Taking into account the limited stock of natural gas in the country and its increasing use in electricity generation (Figure 3), which is being employed in the mining sector, may be jeopardizing the long-term availability of this high quality primary energy resource for use by the rest of society (Figure 2). Potential consequences might include: (a) increasing dependence on expensive energy imports, due to creation of natural gas input flow requirements for electricity plants and indirectly, for the mining sector; and (b) increasing pressure to look for and exploit hydrocarbon prospects in the Amazon, and to push ahead with plans for large-scale hydroelectric plants. Using the MuSIASEM approach, it is possible to consider the structure of this process by illustrating the ways in which electricity is being used across the whole society (at the level n), within the paid work sector (at level n-1), and within both the mining and the energy sectors (at level n-3). An overview of changes in the electricity supply system in Peru is presented in Figure 3, showing the increasing dependence on natural gas and the increasing size of electricity flows into the mining sector.

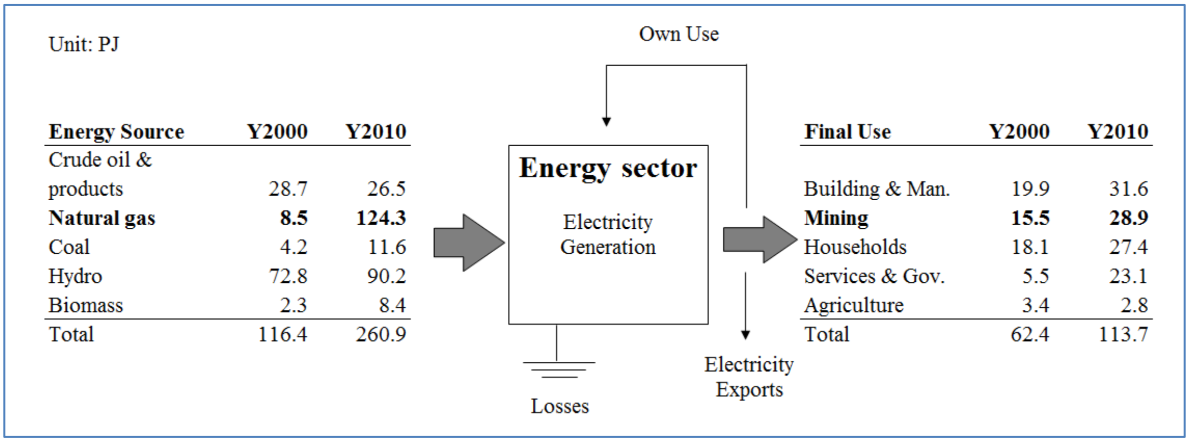


Figure 3: Electricity Generation and Final Use. Source: Own elaboration based in MINEM (2011).

In order to place this review of electricity use in perspective, we can again return to MuSIASEM, where, in Figure 4, a second flow/fund representation is presented: this one comprised, as above, of the fund of human activity (in Gh) but looking this time at the flow of electricity (in PJ) in the paid work sector and comparing this with the mining sector. The MuSIASEM is illustrated using two continuous four-quadrant diagrams, the first one showing the interface between the national economy at level n and the paid work sector at level n-1, and the second one, the interface between the paid work sector at level n-1 and the mining sector at level n-3. Then, from the Figures 3 and 4 is possible to visualize:

- The electricity input flow to the mining sector increases by 86% from 15.5 PJ to 28.9 PJ between 2000 and 2010. This change was possible due to the construction of new electricity infrastructure, which included the power plants that require a continuous input flow of primary energy. That primary energy source is, at present, mainly natural gas (48% in 2010), favoring a carbon lock-in in the national energy system.
- The electricity metabolic rate (eEMR) of the mining sector was 61.55 MJ/h in 2010, which means that 61.55 MJ of electricity were used, per hour of work in the mining sector. As a reference value, the eEMR of the building and manufacturing (BM) sector in Peru was 5.40 MJ/h in 2010 (31.6 PJ / 5.85 Gh), indicating that the mining sector used 11 times more electricity per hour of human activity than the BM sector. While this is not surprising, as mining activities are energy intensive, it gives an indication of the relative importance of electricity in the mining sector.

Then, the mining sector's energy flows estimates for 2020, were calculated as follows:

- The proven reserves of Camisea natural gas (90% of total gas reserves in Peru) were estimated to be 13.87 TCF or 14,568 PJ, calculated at the end of 2012 (MINEM 2013).
- The domestic extraction of natural gas was 502 PJ in 2012 (IEA 2015). Assuming an average domestic extraction rate of 550 PJ/y of natural gas for the next 8 years. Then, the Camisea reserves will be depleted in 4,400 PJ (30%) by the end of 2020.
- The electricity plants used 164 PJ of natural gas in 2012 (IEA 2015). Assuming a domestic industrial use rate of 180 PJ of natural gas for electricity generation in 2020, and assuming, based on established precedent (Figure 3), that 48% of Peru's electricity will be generated using natural gas. Then, total primary energy input for electricity generation will be of 375 PJ (180 PJ/0.48) in 2020.
- The electricity plants transformed 261 PJ of primary energy into 114 PJ of electricity in 2010 (Figure 3). Assuming the same transformation rate for 2020. Then, from (3), total electricity generation will be of 164 PJ (375 PJ*114/261) in 2020.
- The human activity in mining sector (HA_{MH}) was 0.47 Gh in 2010 (Table 2). If we take into account the projected fourfold increase in the size of the mining sector by 2020, due to mining investments. Then, HA_{MH} will be of 1.88 Gh (0.47*4) in 2020.
- Assuming a stable electricity metabolic rate (eEMR) of 61.55 MJ/h for 2020. Then, electricity flows to the mining sector will be of 116 PJ (61.55 MJ/h*1.88 Gh) in 2020. And, the flow share of electricity in the mining sector at the interface of levels n-3/n will be of 71% (116/164) in 2020.

It means that the total expected electricity generation would need to be allocated almost entirely to the mining sector. And, this would be taking place in the context of increasing natural gas scarcity and higher electricity demand across the rest of the paid work and household sectors, due to population growth and urbanization.

The size of the electricity system in Peru has increased by 82% between 2000 and 2010 (Figure 3). The rough estimates presented above predict an increase of 44% between 2010 and 2020. Considering the conservative nature of these estimates, it is possible to argue that the growing mining sector may jeopardize the availability of electricity for the rest of society, over the medium to long-term. It also appears to have good potential to incentivize new environmental impacts by increasing the pressure to secure new primary energy flows, either by increasing extraction of resources across the Amazon, or by increasing energy imports.

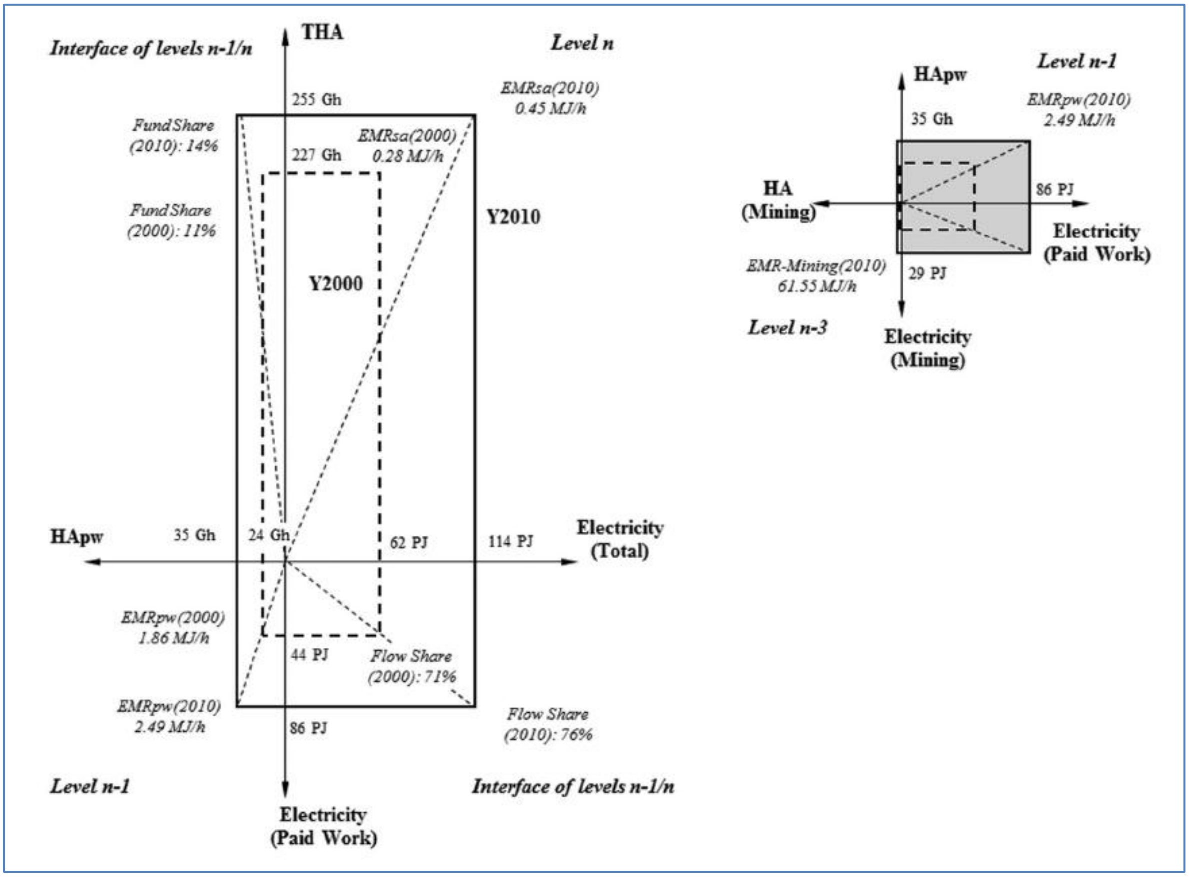


Figure 4: MuSIASEM representation of Electricity Flows and the Mining Sector. Source: Own elaboration based in Giampietro and Mayumi (2009).

Conclusions

The metabolic profile of Peru presented here is based upon and intended to contribute toward a growing body of literature concerned with social metabolism and mineral extraction by using the Multi-scale integrated analysis of societal and ecosystem metabolism, MuSIASEM (Giampietro and Mayumi 2000a, b, 2009, Giampietro 2003) approach to bioeconomics analysis. It is an application of the flow/fund model of Georgescu-Roegen (1971) and provides an integrated study of the fund human activity and the flow exosomatic energy, across multiple economic sectors. More specifically, the empirical data used here is focused on the Peruvian mining sector's electricity flows between the years 2000 and 2010 and includes rough estimates for likely energy demand in 2020, which are projected, based on indicators generated through the MuSIASEM analysis. This information is used to answer the research question – what are the long-term national energy system implications of the recent government-supported growth of the mining sector in Peru? Empirical results found for the national economy (level n in the

MuSIASEM presented above) show: (a) a massive increase in size of the national energy system, which is explained by exploitation of the Camisea natural gas reserves, starting in 2004; (b) Peru is found to have an extremely low rate of exosomatic energy consumption per hour of human activity (EMR), with a societal average of only 3.1 MJ/h in 2010, as compared with industrialized country averages in the range of 30-40 MJ/h; (c) there are growing exports of natural gas, not only directly, as liquefied natural gas but also indirectly, as virtual energy used to generate electricity that is used for export oriented metals extraction; and (d) there is clear potential for establishing carbon lock-in in the electricity sector, due to increasing construction of electricity plants that are using Camisea natural gas as their primary energy source.

Empirical results specific to the mining sector (level n-3 in the MuSIASEM presented above) indicate: (a) a comparatively small increase in size of the exosomatic energy input flows to the mining sector includes a shift in energy carriers, from low quality oil products to high quality electricity, which is not apparent when considering only toe values; (b) the extremely high electricity metabolic rate (eEMR) of the mining sector (61.6 MJ/h in 2010), was found to be 11 times the rate of electricity used per hour of human activity in the building and manufacturing sector in Peru; and (c) it was observed, based on projections made, using the results of the MuSIASEM analysis, that potential increases in the proportion of electricity used in the mining sector (flow share at the interface of levels n-3/n in Figure 4) could jeopardize the availability of high quality primary energy supplies for the rest of Peruvian society. Therefore, in order to maintain the national energy system of Peru operating well in the long-term, based on the present structural changes taking place, it will be necessary to ensure a sufficient supply of natural gas. This implies increasing incentives to precede with hydrocarbons exploration and exploitation activities in the Amazon, which would have direct impacts on biodiversity and indigenous peoples or to increase dependence on expensive energy imports.

In light of these implications, the Peruvian government's strong support for growth of the mining sector may have to be reconsidered. In taking up that challenge, decision-makers in Peru will need to give more attention to relationships between the economy and the environment, that is to say, to social metabolism. It is hoped that the present study will help them in that work. In addition, further research concerning alternatives for transitioning to the use of renewable energy, as well as into the potential impacts of changes in patterns of production and consumption is recommend, in order to identify ways to escape the pending carbon lock-in that appears to be awaiting the electricity sector. In order to conduct such research MuSIASEM analysis of energy flows in the household sector would also be required and are recommended as a follow-up to the present study.

Chapter III

The Flow-Fund Model of Conga: Exploring the Anatomy of Environmental Conflicts at the Andes-Amazon Commodity Frontier[7]

Jose Carlos Silva Macher and Katharine N. Farrell

This paper aims to contribute toward improved understanding of complex ecological distribution conflicts at the commodity frontiers, where increasing metabolism in industrial societies is leading to increased environmental destruction in resource-rich countries throughout the world. The focus of this paper is the Conga gold mine project in northern Peru, where there have been violent clashes between the Minera Yanacocha mining company and the local population, represented mainly by campesinos that live in the highlands of the Andes–Amazon region. We do this by using the flow/fund model developed by Georgescu-Roegen and extended by Giampietro and Mayumi, to help us trace the anatomy of this conflict, using simplified representations of the central economic processes involved: gold mining and milk production. By complementing the concept of Ricardian land—an indestructible fund—with the concept of land materials, which is susceptible to qualitative change, and therefore can be either a fund or a flow element of the economic process, we illustrate that the gold extraction process, which treats this land material as a flow, stands in conflict with the milk production process, at least in part, because that process is using these land materials as a fund, i.e., in order to make production possible. The paper employs the concept of environmental valuation triadics, developed by Farrell, in order to explore how the boundaries—physical frontiers and temporal durations—of a specified economic process are related to flow/fund element identities. We conclude with some reflections on potential future applications for the methods employed and on the implications of our analytical results.

1. Introduction

Precious metals mining has long been identified with exploitation of the global south by the global north (Martínez-Alier 2010[2002]; Moore 2000; Muradian et al. 2012; Pérez-Rincón 2006; Russi et al. 2008) and much has been done in recent years to address both the financial and environmental inequalities that come with this activity: primarily with regard to occupational health and safety, contamination control, taxes and royalties, and

[7] Silva-Macher, J.C. and Farrell, K.N. (2014) The flow/fund model of Conga: exploring the anatomy of environmental conflicts at the Andes-Amazon commodity frontier, *Environ Dev and Sustain* (2014) 16: 747-768. DOI: 10.1007/s10668-013-9488-3

transparency agreements (IIED and WBCSD 2002; EITI 2011). However, the recent massive spike in the price of gold, from approximately 450 USD per ounce in 2005 to over 1,500 in 2012 (Bloomberg 2013), has led to a gold rush in Latin America that is bringing to the fore aspects of these conflicts that cannot be resolved through technological improvement because they are bound up with the act of extraction itself, as opposed to depending solely on the quality or even quantity of extractive activity being proposed. The importance of addressing these more foundational aspects of environmental resource conflicts has been highlighted recently by Martinez-Alier et al. 2010 and Muradian et al. 2012, who employed the concept of social metabolism as a heuristic for examining their structure in more detail. More specifically, they have sought to identify systemic relationships between the exploitative metabolism (material and energy throughput) of large transnational corporations and accompanying local conflicts, in an effort to better understand how increasingly globalized demand for material and energy flows can be expected to impact local communities and global society as a whole, in coming years. Here we develop of an alternative to their approach, based on the flow-fund model of Nicholas Georgescu-Roegen as elaborated by Giampietro and Mayumi (2000a; 2000b). Our empirical point of focus is the ongoing conflict surrounding the Conga project in the Peruvian Andes, where a group of campesinos (rural peasants) and the Minera Yanacocha mining company (associated with key Peruvian and international economic interest), are in the midst of a violent and sometimes lethal standoff. Using the flow-fund model to help structure our analysis, we are able to identify a basic contradiction between the objectives and associated structures of the agriculture (milk production) and mining (open pit gold and copper extraction) processes at the heart of this conflict: for the campesinos "Land" comprises soil, surface water, aquifers, and rocks, forming a unity of funds, that can be called the "Mountain" whereas for the mining company, this mountain is an input flow destined to be transformed into a product (minerals concentrate) and wastes (tailings, wastes rocks, wastewater).

The Conga conflict can be understood as an archetypical metals extraction conflict, with a structure repeated throughout Peru, Latin America and the world: local economic processes of the campesinos' livelihood (e.g. food production, community building, education in rural practices), in conflict with the international economic process of metals extraction. Our study is structured using the flow-fund analytical economics approach developed by Nicholas Georgescu-Roegen (1976[1965]; 1971) and elaborated by Giampietro and Mayumi (2000a; 2000b; 2004; 2009). This approach distinguishes between elements of economic processes through reference to the purpose(s) of the economic activity in question (Farrell and Mayumi 2009) and enables us to develop distinct but comparable representation of the conflicting economic processes of mining companies and local communities, in order to sketch the anatomy of this environmental conflict. Using Georgescu-Roegen's flow-fund theory, we identify basic elements of economic production, such as – land, water, gold and money – that make it possible to trace the structure and consequences of the conflicting economic purposes that lie at the heart of the Conga mine conflict. On the one hand, the land and water of the Conga region are inextricably connected to the biological life upon which the livelihood of the campesinos depends; on the other hand, income from the sales of the gold that lies inside that land and amidst that water –the main target metal for the Conga mine – is inextricably connected to the financial performance of Minera Yanacocha.

Our analysis is presented in five sections. First, we provide general background information about the Conga mine. Next, we introduce the question of purpose, by linking Georgescu-Roegen's flow-fund theory to the concept of valuation triadics (Farrell 2007), which makes it possible to distinguish between the respective flow-fund elements that comprise the production processes of interest to the campesinos and the mining company, respectively. We then provide a brief overview of our data collection methods and a description of the anatomy of the environmental conflict of Conga, based on a combination of the purposive information drawn from the valuation triadics assessment and the application of the multi-scale integrated assessment of societal and ecosystem metabolism (MuSIASEM) tool developed by Giampietro and Mayumi (2000a; 2000b). We conclude with some reflections on the proposed methodology, including an assessment of its strengths and limitations and on the implications of our analytical results.

2. The Conga mine

The Conga mine is a large-scale open pit gold mining project proposed in the Department of Cajamarca to the north of the Andes Cordillera in Peru. The project overlaps with three rural farming Districts: La Encañada, Huasmín and Sorochuco; and with five river basins: Toromacho, Alto Jadibamba, Chugurmayo, Alto Chirimayo and Chailhuagón, the waters of which flow into the Marañón and then the Amazon River. The project is exploitation of two mineral deposits, the Perol and the Chauilhuagón, discovered in 1991. The mining company, Minera Yanacocha, consists of Newmont Mining Corporation (51.35%), Compañía de Minas Buenaventura (43.65%) and the World Bank's International Finance Corporation (5%). The decision to develop the Conga mine was made in 2004, prior to the conducting of an environmental impact assessment (EIA), which was presented in February 2010 (EIA 2010a) and approved by the government of Alan García in October 2010, despite the absence of a complete hydro-geological study. Although Ollanta Humala made an electoral promise to stop the Conga mine, after becoming President of Peru, in July 2011, he reneged on this, creating substantial controversy at the national level. Humala's support for Conga increased the intensity of an existing environmental conflict between campesinos in the region and Minera Yanacocha, which has, to date, led to the violent deaths of five local citizens[8]. . It is alleged that these fatalities occurred due to the excessive use of force by the police and security forces during the protest against the extractive project (Amnesty International 2013; CNDDHH 2013).

The economic process of the Conga mine can be represented through reference to the following core elements, or factors of production: (a) Ricardian land, understood as the area capable of capturing solar energy and rain; (b) supplies for extractive work and maintenance: water, electricity, fossil fuels, explosives, chemical reagents, and machinery parts; (c) land materials, understood as the space containing: topsoil, rocks, metal ores, and aquifers; (d) products: metals concentrate containing gold, copper, silver, and other valuable minerals; (e) wastes: rocks, tailings, wastewater, and air emissions ; (f) capital proper: mine infrastructure and vehicles; and (g) labor power: executives, employees and contractors. The planned duration of the mining process is 19 years, including 2 years of construction and 17 years of operations. The standard annual operation consists of the removal of overburden (topsoil and rocks) in order to obtain low-grade metal ores, which are then concentrated using a combination by physical and chemical processes that entail very intense use of water. The metal products are sold on the international commodity market, while the land wastes, including rocks, degraded land and chemical residues remain in the mine area. The Ricardian land area used in the Conga mining process physically overlaps with the Ricardian land area used by campesinos as grazing lands for milk production. We take this overlap as the starting for selecting our primary scale of reference. The total area of the Conga river basins, which we define as the Ricardian Land used by the campesinos of the region, serves as our first reference value and the common context for our comparative analysis of the two processes (level n in Fig. 2). Following Giampietro and Mayumi (2004) we use the campesinos' economic process of fresh milk production as a representative, or token, activity that provides a concrete basis for tracing the complex array of economic processes through which they maintain their livelihood. This process can be represented through reference to the following elements: (a) Ricardian land; (b) supplies: life giving inputs from the environment: surface and shallow groundwaters (lakes, rivers, springs, upper groundwater), rainfall, nutrients flows, and solar energy; (c) product: fresh milk; (d) land materials: topsoil, landscape structuring rocks, and aquifers; (e) wastes: solid wastes, wastewater, and air emissions; (f) capital

[8] Defensoría del Pueblo: http://www.defensoria.gob.pe ... reports the death of José Eleuterio García Rojas (40), José Silva Sánchez (35) and the teenager C. M. A. (17) in July 3rd, 2013 in Celendín, Cajamarca.
La República News: http://www.larepublica.pe/06-07-2012/muertos-en-cajamarca-suben-5-mientras-la-region-vive-en-un-clima-de-tension ... reports the death of Joselito Vásquez Jambo (26) and José Antonio Sánchez Huamán in July 5th, 2013.

proper: dairy cows, farms and other facilities; and (g) labor power: campesinos. Unlike the mining process, the temporal boundary of the milk production is ostensibly indefinite.

In addition to these material elements, both the mining and milk production processes have financial elements. For the mine there is gross capital investment; expected revenues from sales of gold, copper, silver and other minerals; expenditures related to operations, including purchases of flows, salaries and project financing; taxes and royalties, including the canon minero for local governments (50% of the income taxes); and finally a net profit for the shareholders of the company. For the milk production process, there is capital investment in upkeep; revenues from sales of fresh milk (part of which is produced for own-consumption), and expenditures for the acquisition of market based supplies for the campesino household. Here it is important to note that the agricultural activities of the campesinos of Conga do not serve to meet all their basic needs. The national and local governments have to facilitate the supply of infrastructure for potable water, wastewater treatment, roads, electricity, and communications, as well as the supply of public services for nutrition, health, and education (INEI 2007).

The Conga mine has been presented by Minera Yanacocha as a state-of-the-art enterprise and the project plans do include advanced contamination controls and heightened attention to local impacts, when compared with previous mining projects in Peru (EIA 2010a; Newmont 2012). However, the physical reality is that the target metals at the Conga mine are dispersed and can only be accessed through aggressive intervention that will leave behind an open pit where once was a mountain. This inevitable transformation of the landscape, including the massive shifting of land materials, introduction of processing chemicals and the elimination of surface lakes and the aquifers below them, lies at the heart of the Conga conflict. While technology can help reduce the risks associated with processing chemicals and mine drainage, the only way to avoid moving the land materials and eliminating the threatened lakes would be to leave Conga's gold in the ground. Taking this basic feature of the conflict as our starting point, we can identify a set of elements that make it possible to represent the basic structure of the relationship between the metals mining and milk production processes: land materials: topsoil, rocks, metal ores, and aquifers; water flows; products: metal concentrates and fresh milk; wastes: liquid and solid; Ricardian land; labor power and monetary flows. As the public debate over the Conga project centers on the use of water[9] and the flow of money we

[9] The hydrogeological component of the Conga EIA was subjected to an International Expert's Review in April 2012 as the result of public pressure questioning the quality of the EIA. However, the controversy was not solved due to criticism on the part of opponents regarding how the government selected the Auditor Team. Nonetheless, this Expert Review raised additional concerns.

focus our analysis in particular on these two elements, building in representations of Ricardian land, land materials, milk, metals and wastes, where appropriate.

3. Application of the Flow-Fund Model to the Conga Conflict

According to the flow-fund model of Georgescu-Roegen (1971), an economic process can be represented by a combination of fund elements, which facilitate a production process, and flow elements, that cross the process' spatial and temporal boundaries: "Flows are elements that enter but do not leave the process, or conversely, elements that exit without having entered the process. Funds (e.g. capital, people, and Ricardian land) are elements that enter and exit the process unchanged, transforming input into output flow" (Mayumi 1999, p181). This means that an element's identity, as either a flow or fund, is process specific, depending on the relationship between that element and the spatial and temporal boundaries of the economic process in question. Building on Farrell and Mayumi's (2009) study of Georgescu-Roegen's critique of the Wicksteaedian production function, we understand this process specificity to be related to the purpose of the economic process in question. The relationship between purpose and the positioning of an economic process in space and time can be understood using the metaphor of cuisine: "Differences between cuisines reflect not only different ingredients but also the application of different sets of tradition, in the form of different recipes… [which] include instructions regarding how the ingredients are to be combined..." (Farrell and Mayumi 2009, p303). Cuisine implies choices regarding to what end the elements of an economic process will be used, i.e. regarding purpose. These choices play an important role in determining both the spatial and temporal boundaries of an economic process: how much material and which physical spaces are required? how long should each step last? when should it start and end? A hypothetical case of alternative purposes concerning the use of an apple tree can help to illustrate our point. Let us imagine a carpenter and a farmer observing the same tree. The spatial boundaries of their respective economic processes are roughly the same: the tree and its immediate nutritive environment. But, the duration of the economic process of interest to the carpenter, i.e. that associated with the purpose of extracting timber, is the time required for cutting the tree (e.g. some hours), while for the farmer it is the productive life of the tree (e.g. many years). The carpenter is thinking in terms of accumulating a timber stock, which can serve as an input flow element in their workshop, in the economic process of making tables, whereas the farmer is thinking of the tree as a source of apples, that is to say as a fund element, with the apples it produces being the output flow element. Here we have the core components of a typical environmental conflict: one resource and two, incompatible, and in this case mutually exclusive purposes. In the language of the flow-fund model, we may say that what is contested here is the element identity of the tree. In the case of the conflict over Conga it is the element identities of Conga Mountain and the associated groundwater.

In order to better understand the relationship between two conflicting economic processes we can explore in detail how their respective purposes are related to the respective flow-fund element identities implied by their respective spatial and temporal boundaries. In their study of this relationship, Farrell and Mayumi (2009) link the process specificity of element identity to what Georgescu-Roegen (1971:362) has called Anschauung (visualization or perspective), which shapes how the specific purpose of a given economic process is defined. In our example above, the Anschauung of the carpenter would be table production, that of the farmer, apple production. When they meet at the tree, the economic purpose of the carpenter, which is logically related to their Anschauung, is to get wood for making tables; that of the farmer is to harvest fruit. Through this reference to Anschauung, it is possible to trace the relationship between the respective economic purposes of different economic actors involved in a resource conflict and the concrete material characteristics of the contestation, which can be represented as competing flow-fund element identities.

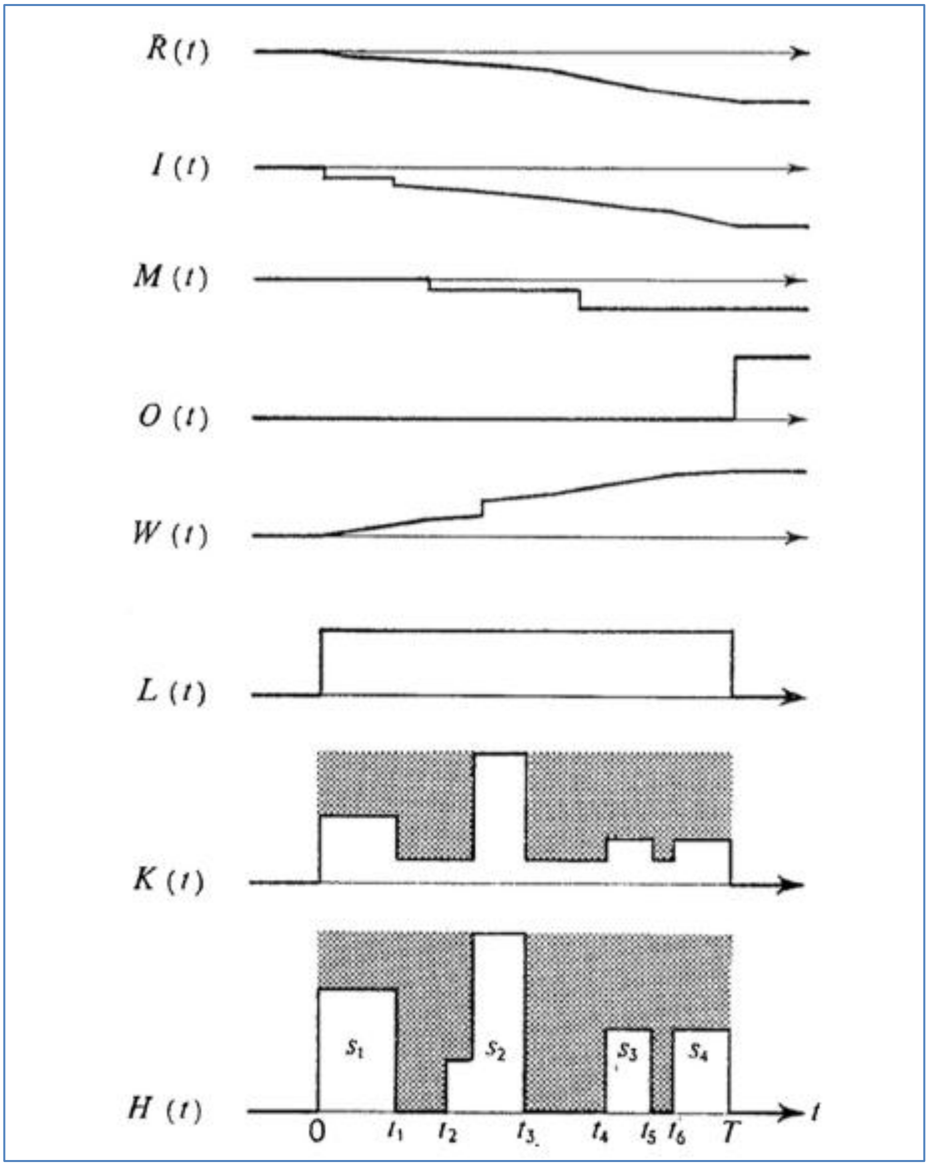
In order to provide a concrete basis for documenting the relationship between Anschauung and element identity, we use the concept of environmental valuation triadics (Farrell 2007), which provides a complex representation of what Farrell and Vatn (2004) call value articulation (see also Vatn 2005; Farrell 2009[2005]; 2007). A valuation triadic is comprised of three hierarchical levels: (1) higher (structure - value system), (2) focal (focus – perception of the object of valuation), and (3) lower (functional – articulated values) (Farrell 2009[2005]; 2007). The three categories can be used to describe, respectively, the preconceptions, perspectives and recommended actions of different actors concerned with a given environmental conflict. The higher (structure) level of a triadic can be related to Anschauung; the focus, to the specific economic purpose of a given process; and the function to the specification of element identity, because it defines the concrete spatial and temporal boundaries of the specific economic process in question. In this way the valuation triadic serves as a complement to the flow-fund model, providing us with a way to trace the roots of an environmental conflict, happening at the focal level, from the structural level, where we can observe motives, or final cause, through to the functional level, where we can observe the concrete implications that conflicting economic purposes have for the process specificity of element identities.

In the case of Conga mine, both land and water are fund elements, from the perspective of the campesinos, whereas these are flow elements from the perspective of the mining company. In this paper we explore the anatomy of this conflict, using the flow-fund model and find that the current set of flow-fund relationships do not allow for a compromise solution. While it might be argued that this is obvious, we propose that our detailed flow-fund analysis of the anatomy of this conflict, which builds on Giampietro and Mayumi's (2000a; 2000b) MuSIASEM approach, provides valuable information regarding how and at what critical points in the respective production processes, the irresolvable character of this conflict manifests. Such information could, in principle, then be used to explore how the respective production processes might be adjusted, in order to improve their compatibility: i.e. to identify alternative production strategies that could fulfill the same purposes without triggering an irresolvable conflict.

A key feature of the MuSIASEM approach to operationalizing Georgescu-Roegen's flow-fund model is the way that it manages the mathematics of functionals, which are discussed briefly, but at a pivotal stage in the development of the model (Georgescu-Roegen 1971, p231-236). At this stage in the development of the model, Georgescu-Roegen gives particular attention to the importance of taking the role of the passage of time into account, when analyzing the characteristics of a process of economic production. "[Where], T represents Time, conceived as the stream of consciousness or, if you wish, as a continuous succession of moments, but t represents the measure of an interval (T', T'') by a mechanical clock" (Georgescu-Roegen 1971, p135). A representation of a production process might include functions such as: (1) Flow elements: R(t): inputs of the so-called natural resources; I(t): the current input flows of the materials which are normally transformed into products and which come from other production processes; M(t): the input flows needed for maintaining capital equipment intact; Q(t): the output flow of products; W(t): the output flow of waste; and (2) Fund elements: L(t): Ricardian land; K(t): capital proper; H(t): labor power.

Since the flow-fund model representation is a functional, instead of solving for individual values, it is solved for functions, relating the value of a function (or set of functions) at some point (t1 = 0) with a value or values at another point (t2 = T). An easy way to understand a functional equation of the type employed in the flow-fund model is through graphical representations, where alternative time steps can be compared using a set of parallel graphs, with common specified time intervals (see Fig.1). Comparison is possible because all functions are related the same temporal boundary, i.e. are of the type f (t).

Figure 1: Representation of a Flow-Fund Model



Source: Georgescu-Roegen (1976[1965], p89)

This type of representation illustrates the respective relationships of the elements to the temporal process boundaries and gives a clear visual representation of their status as either a flow (with an amount that changes over time) or a fund (the amount of which is stable over time). Much of this comparative information is lost if the functional logic underpinning the flow/fund model is disregarded, including the kind of information we wish to explore here, regarding how rates of flows and of fund depletion of are related to one and other, over time. Giampietro and Mayumi's (2000a; 2000b) MuSIASEM, which is an application of Georgescu-Roegen's flow-fund model, allows us to retain this information because it employs the principle of functional mathematics by juxtaposing flow (right x and bottom y axes) and funds (top y and left x axes) in a four quadrant graphical representation that illustrates a selected set of four key functional flow-fund relationships, distributed across two hierarchically related levels, for a given economic process: β − share of level 1 fund employed at level 2; α − flow/fund ratio at level 1; γ − flow/fund ratio at level 2; and δ − share of level 1 flow employed at level 2.

Since both the valuation triadic and MuSIASEM are based in hierarchy theory (Salthe 1985; Mayumi 1999), we can use information drawn from our review of the valuation triadics associated with the conflict (detailed below) to move up and down across a hierarchically structured representation of the conflict, shifting the point of focus, in order to examine how different purposive aspects of the conflict are related to different concrete flow-fund relationships. For instance, in the Conga mine conflict, by employing a hierarchical representation that takes into account the respective time frames of Minera Yanacocha and the campesinos, we can examine the flow-fund consequences of their different time perspectives, or Anschauung. For Minera Yanacocha, the Conga project, which is expected to last for 17 years, is the main point of focus and the land, water, gold and money are all seen as parts of the project. For the campesinos, it is rather the Conga region, which is timeless with respect to the duration of the milk production process that is the point of focus in their conflicts with Minera Yanacocha.

In order to apply these concepts to the Conga case, we need first to specify more clearly what we mean by land. In the functional equation elaborated by Georgescu-Roegen (1976[1965]), land refers specifically to Ricardian land: i.e. a physical substrate and location, as distinct from its other productive qualities. It is understood as a fund that provides a substrate capable of supporting humans and infrastructure and of capturing solar energy and rain; Ricardian land does not include soil or the nutrients in the soil (Daly and Farley 2011[2004]). However, in the Conga case, land is a dialectical concept[10], the definition of which depends on the final cause or cuisine preferences of a specified social actor. For the campesinos land is more than just location, balancing all the elements necessary for life, in a complex unity that includes the topsoil, structural rocks (mountains), water flows and aquifers, as well as the living species (plants, animals, and humans). This complex set of elements can be understood as what Georgescu-Roegen (1976[1965]:93) has called a process fund, whose presence within a production process is

[10] Regarding the fundamental law of Logic, the Principle of Contradiction, "B cannot be both A and non-A" ... we must accept that, in certain instances at least, "B is both A and non-A" is the case. Since the latter principle is one cornerstone of Hegel's Dialectics, I propose to refer to the concepts that may violate the Principle of Contradiction as *dialectical* (Georgescu-Roegen, 1971: 46).

a necessary precondition for the outflow of materials from that process. For example, while the water of the aquifer that would be eliminated by the open pit is not necessarily consumed in the milk production process, its presence is a precondition for the availability of surface water in the associated lagoons and springs, which are. On the other hand, for the mining company, land can also be the place where valuable minerals (i.e. gold, copper) are located, which can be extracted by the removal of non-valuable materials (topsoil, rocks, aquifers, and living species). This later concept is closer to the Anschauung found in the valuation system of a mining company. In order to produce a flow/fund based analytical representations of the Conga mining process, in which land is transformed, and so should be classified as a flow element, we add to the concept of Ricardian land (a fund), measured as land area (km2), a dialectical companion element of potentially transformed land (fund for the campesinos, flow for the mining company), which we measure as land materials, calculated in land materials tons which combine the land solids (tons of topsoil, rocks, and metal ores) and land water (tons of aquifer water) that would be transformed, through the mining process, into metal concentrates (gold, copper, silver, etc.) and wastes (tailings, waste rocks, and wastewater).

4. Methods of Data Collection

Our data is based on secondary sources, which include mainly the Conga mine Environmental Impact Assessment (EIA 2010a; 2010b; 2010c; 2010d; 2010e; 2010f), the National Population and Housing Census of Peru (INEI 2007), the National Agricultural Census of Peru (INEI 1994), and the Statistical Compendium of the Department of Cajamarca (INEI 2009). We collected relevant information on land area, land materials, water flows, milk production, gold and copper extraction, and monetary flows. These data were processed (see Annexes I and II) to provide rough estimates of the different values required for the construction of a set of representation of selected flow/fund element relationships, based on the MuSIASEM approach, across temporal and spatial scales. Complementary information was collected from the review of the Conga EIA (2010) developed by Moran (2012), who is an expert hydrogeologist with relevant experience in the mining sector, and as also from an international experts' review of the hydrological component of the Conga EIA, prepared by Fernández et al. (2012) for the Peruvian Premier's Bureau. This array of sources allows us cross reference information, in order to develop a reasonable estimate of the quantity and quality of the water resources inputs and outputs, which has be a subject of substantial controversy. Here it is important to note that mining companies do not normally allow continuous environmental monitoring conducted by independent professionals, so we are dependent to a large degree on triangulated information, when considering potential impacts of the mine. We also, in some cases, apply technical coefficients collected from the Yanacocha gold mine (Minera Yanacocha 2010; 2012), which is roughly equivalent to Conga in its process.

5. Analysis

The analysis comprises three parts: 5.1) first we sketch valuation triadics for the campesinos and the mining company; 5.2) we then carry out partial multi-scale integrated analyses of societal and ecosystem metabolism (MuSIASEM) of the minerals extraction, the milk production process and the relationship between the two processes; and 5.3) finally we discuss the results of these partial analyses.

5.1. Valuation Triadics

5.1.1. Mining Company

The mining company in Conga is Minera Yanacocha, which includes Newmont Mining Corporation from United States. Newmont is one of the world's largest gold extractors and is listed in the Standard & Poor's 500 index. According to its Annual Report and Form 10-K[11] (Newmont 2011), the company's annual sales in 2011 were 10.4 billion USD, net income of 502 million USD, with an operating margin of 971 USD per ounce of gold, at an average realized gold price of 1,562 USD/ounce. The company has an operating history of more than 90 years, which includes serious controversy in Peru over claims that Newmont met with Vladimiro Montesinos, the corrupted accomplice of the Fujimori dictatorship in the 1990s, in order to take advantage of a legal dispute with a French company over control of Minera Yanacocha (Morris 2010).

The following valuation triadics describe the characteristics of how this typical mining corporation views the Conga area and the respective elements of land, water, gold and money. As is also the case with the campesinos description presented below, this representation is an interpretation, based on our review of available literature. It is intended to reflect in a general way, how this actor perceives the focal objects of analysis. It can most certainly be contrasted with other points of view and we do not claim it to be so much an accurate as a plausible and analytical useful representation (sic Box 1979). Our aim is not to give a definitive description of a mining company valuation triadic but rather to provide a transparent picture of the triadic that we assume here, for the purposes of our analysis.

[11] A Form 10-K is an annual report required by the U.S. Securities and Exchange Commission (SEC) that gives a comprehensive summary of a public company's performance.

Table 1: Valuation triadic for the mining company

Focal point	Structure	Focus	Function
Conga	To make profit for shareholders.	Conga is a place to make profit for shareholders.	Extract and sell market valuable minerals such as gold, copper, and silver, among others.
Land	Conga is a place to make profit for shareholders.	The land contains gold, copper, silver and other valuable minerals.	Extract all the possible valuable minerals from the land.
Water	Conga is a place to make profit for shareholders.	The water is a key natural resource for the mining process.	Use the water and substitute natural lakes with water reservoirs in order to control the water flows.
Gold	Conga is a place to make profit for shareholders.	The gold has a high price in the global market.	Sell the gold to maximize profit.
Money	Conga is a place to make profit for shareholders.	Conga has a high return on capital investment.	Make a large capital investment in the Conga Project.

Source: Own elaboration

5.1.2. Campesinos

Here it is important to begin by noting that there is no universal concept of 'peasant community' in the Peruvian Andes (Urrutia 2006; Cadena 2010). Instead there is a mixture of concepts, of rural life and rural communities, influenced by the Pre-Colonial, Colonial and Republic periods in Peru's history, and today also by globalization. In addition, there is ongoing demographical change, with both emigration from and population growth within rural areas, both of which have served to change the idea of what it means to be campesino: one who is of the countryside. In the department of Cajamarca, where Conga is located, the rural population was 624,081 habitants in 1961, making up 85% of the population, and 933,882 habitants in 2007, making up then only 67% (INEI 2009). Moreover, agrarian reform, civil war, and authoritarian rule have all influenced the characteristics of peasant communities in Peru (Urrutia 2006). However, according to Urrutia (2006) the problems perceived by the campesinos are similar to 40 years ago, when the anthropologist Henry Dobyns published his book "Comunidades campesinas del

Perú" in 1970. They include: aridity or water scarcity; disputes over territorial boundaries; land owner aggression; alienation from the central government (72% said that the government do not support and discriminate peasant communities); lack of integration in voluntary associations (only 15% said that have participation in peasant organizations connected to political parties); and lack of communication infrastructure (59% said that their communities do not have enough communication ways, and 45% answered that the campesinos constructed their own access roads with communal work).

The following valuation triadics characterize a simplified version of campesinos, which we again do not claim is correct but rather analytically useful for our purposes here. We presume for our simplified representation, the Anschauung of the milk producing campesinos that are grazing their animals within the area of the five river basins that would be impacted by the Conga mine. Our reference data for these triadics is a combination of statistical information about campesinos activities in the region, Urrutia's (2006) anthropological study, Cadena's study (2010) on indigenous cosmopolitics in the Andes, and literature relating to current campesinos protests in the region (CNDHH 2013; Defensoría del Pueblo 2013). As above, we present valuation triadics for five focal objects: the Conga region, land, water, gold and money.

Table 2: Valuation triadics for the campesinos

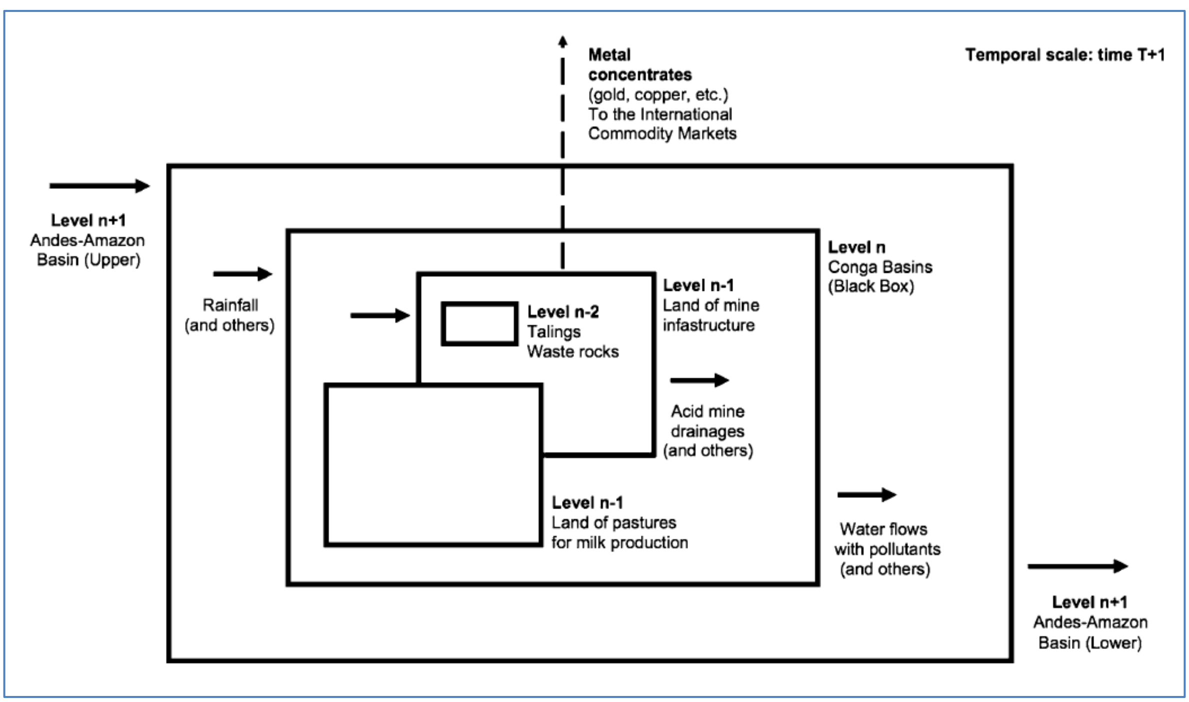
Focal point	Structure	Focus	Function
Conga	Living well.	Conga is part of the land and water. Minera Yanacocha is a threat to survival.	Strong and persistent public strikes against the Conga mine.
Land	Conga is part of the land and water. Yanacocha is a threat to survival.	The land is the agro-ecological system of the Andes, which is the base of the peasant economy.	The land has to be maintained for continuous provision of water, food and fodder.
Water	Conga is part of the land and water. Yanacocha is a threat to survival.	The water is a key part of the agro-ecological system in the Andes, which is the base of the peasant economy.	The water has to be maintained for the continuous provision of food and fodder.
Gold	Conga is part of the land and water. Yanacocha is a threat to survival.	The gold is a part, but not a key one, of the agro-ecological system in the Andes.	It is not necessary to extract the gold from the mountains.
Money	Conga is part of the land and water. Yanacocha is a threat to survival.	The products of the Conga land can be sold at the markets in order to obtain money.	Sell agricultural products at the local and regional markets

Source: Own elaboration

5.2. MuSIASEM

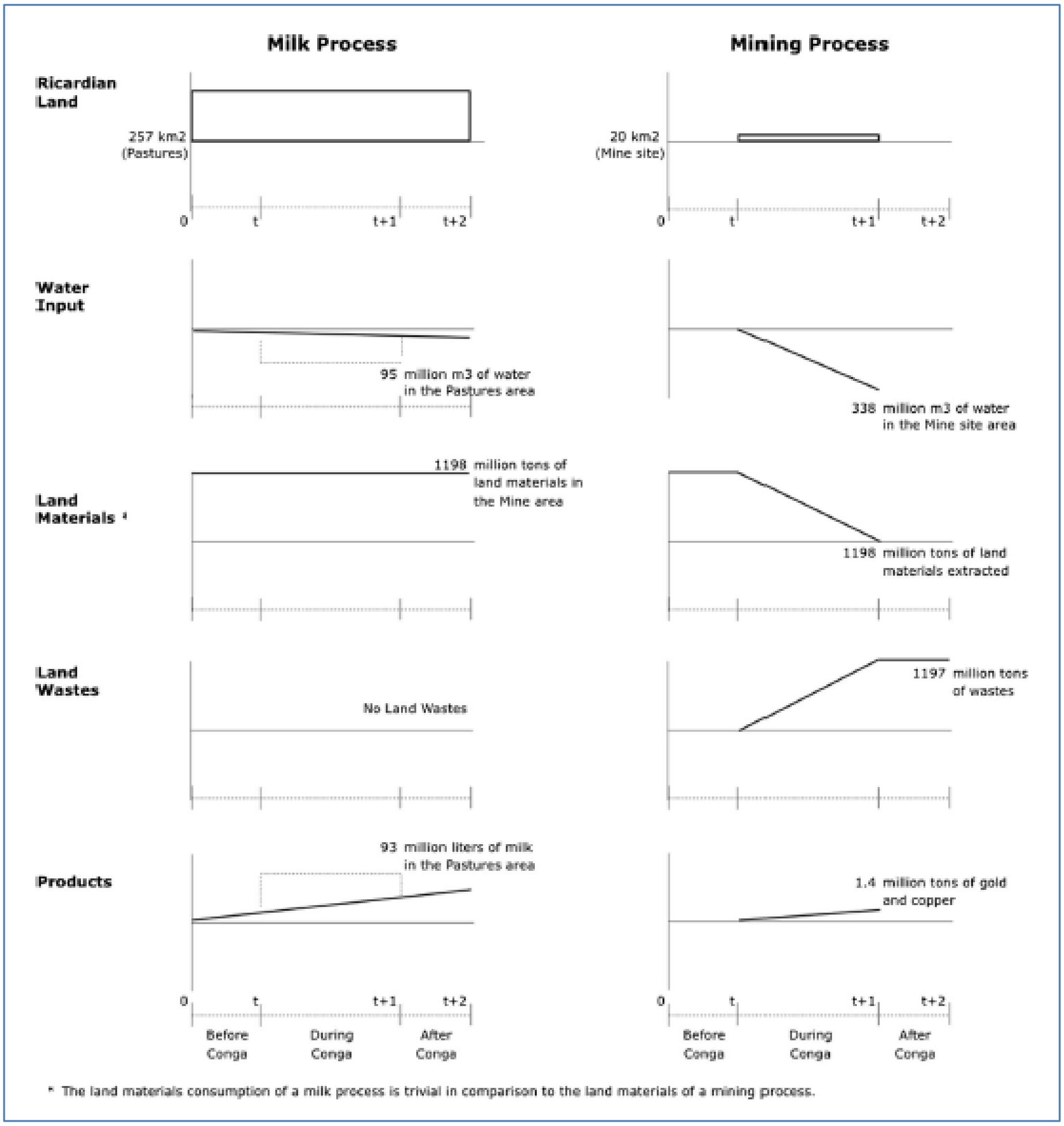
We define the initial boundary for our analytical representations through reference to spatial location, taking the land area of the five river basins of the region as our reference point, or level n (see Fig 2). We start with this area for two reasons: (1) because the water flowing toward Conga is required by the mining operations and (2) because the extractive activities planned for Conga mine would radically modify water system flowing from the site. We use the concept of Ricardian land (a fund), to identify the specific areas where infrastructure for minerals extraction and land use for milk production are located. This land area is the level n-1 in Fig.2, where the competing land use demands of campesinos and the mining company are represented. The overlap between the mining and the campesinos n-1 boxes represents extraction and alteration of topsoil, rocks and metal ores in the 20 km2 of mine infrastructure and second potential contamination of the water system. While there are also threats to air and soil quality, to plant, animal and human health, and potential impacts in the Marañón and Amazon Rivers, we do not include these in our calculations: they fall into the external context or level n+1 (Fig. 2). Also, we include the Fig. 3, which is an schematic flow-fund model representation of the whole Conga metabolic process in order to facilitate understanding of the subsequently graphical representations.

Figure 2: Flowchart of the Conga metabolic process



Source: Own elaboration inspired in Giampietro and Mayumi (2004)

Figure 3: Flow-fund model of the Conga metabolic process



Source: Own elaboration inspired in Georgescu-Roegen (1976[1965])

Temporally, we have a continuous succession of moments (time T) that begins before the Conga Project, where the land is not radically modified, followed by a 17 year period of proposed plant operations (time T+1) and then the new context, after the mining process, which includes potential long-term contamination of the water system and the permanent removal of part of the Conga mountain (time T+2). As we move across these time steps we can observe how the two valuation systems described above come into conflict, as their respective spatial and temporal relationships to the element land materials give rise to a flow-fund ambiguity (Fig. 5). For the campesinos, to live well implies, among other things, to have clean water and the possibility for a sustainable agricultural economy, though, for example, fresh milk production. The land area and its material components, including land materials – i.e. topsoil, the rocks (and metal ores), and the aquifers – have to be maintained over time, in order to provide clean water and biomass. For the campesinos land materials should enter and exit the economic process unchanged: i.e. it is a fund element. For the mining company to make a profit implies, among other things, to extract gold and copper from these land materials. This process implies a radical modification of land materials, which should exit the mining process as product and waste: i.e. it is a flow element.

Table 3: Parameters of the Conga metabolic process

Focal point	**Conga Land – *Campesinos***	**Conga Land – Minera Yanacocha**
Purpose	Agriculture	Mining
Duration	Actual and Next Generations	Extraction time
Spatial Frontier	Land Area, including Land Materials	Land Area, including Land Materials
Element Identity	Land Materials = Fund	Land Materials = Flow
Flow Data	Tons of water and biomass per year	Tons of gold and copper
Duration scales	T: Before Conga project T+1: During Conga project (17 years) T+2: After Conga project	T+1: During Conga project (17 years of plant operations)
Frontier scales	Level n-1: Pastures area Level n: Conga river basins Level n+1: Amazon River Basin	Level n-1: Mine infrastructure area Level n: Conga river basins Level n+1: Commodity Markets

Source: Own elaboration

In the following series of graphical representations we apply the MuSIASEM framework of flow/fund representations to highlight how this flow/fund ambiguity is related to the anatomy of Conga's environmental conflict. The nested hierarchical levels of the MuSIASEM analysis are described, following Giampietro and Mayumi (2004), in Fig. 2 above. We presume operations of the gold mining plant operations to be geographically bounded by the 20 km2 of site infrastructure, as the point of reference (Fig. 4). Figures 6, 7, 8, and 9 then move across the anticipated time steps of before, during and after the mining project, and between the two conflicting perspectives of the mining company and the campesinos. This makes it possible for us to trace the qualitative changes of land and the potential consequences for the campesinos, who are opposing the mine.

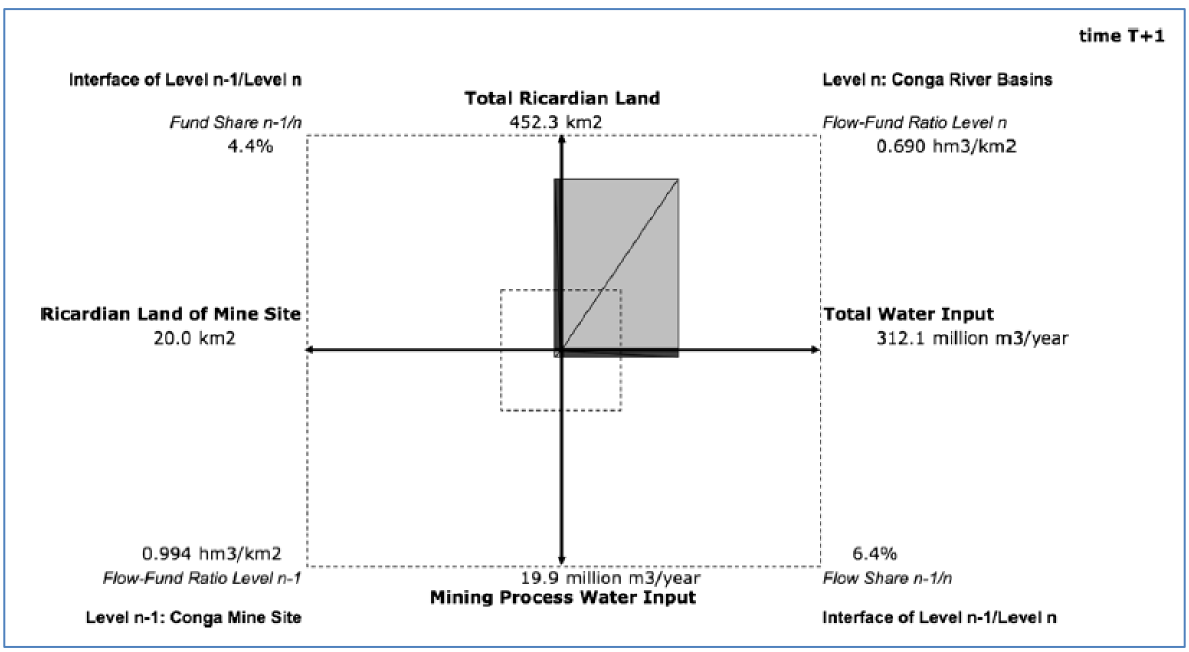
5.2.1. Mining Company

See Figs. 4, 5, and 6.

5.2.2. Campesinos

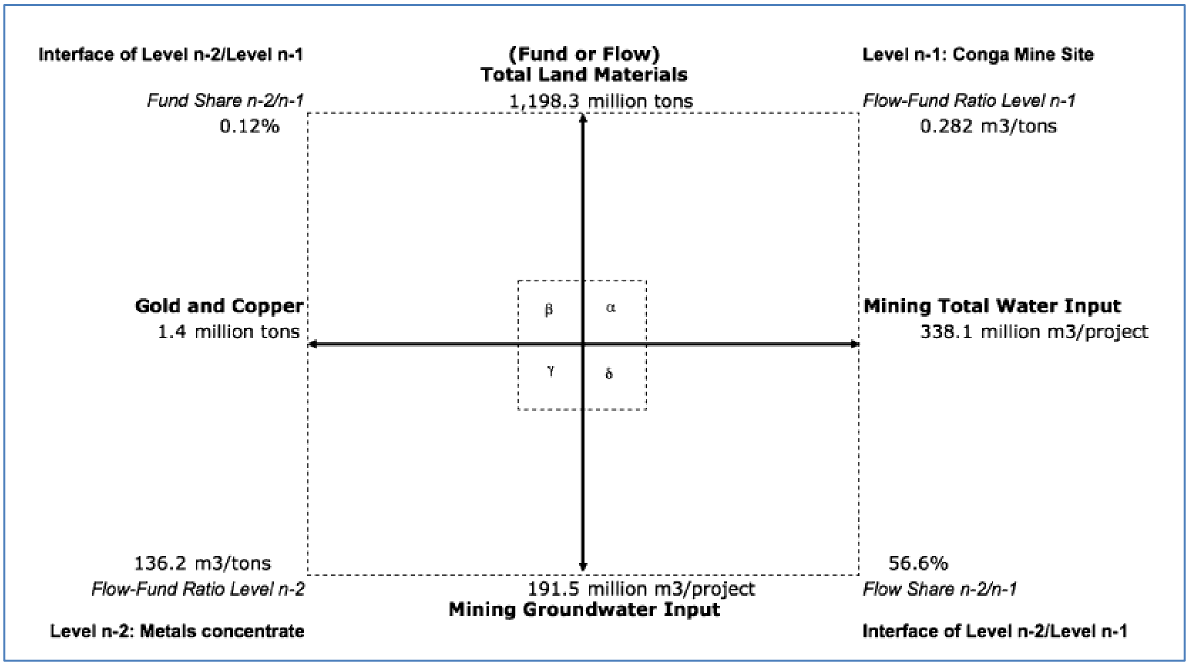
See Figs. 7, 8, and 9.

Figure 4: Ricardian Land vs. Water Input (mining process)



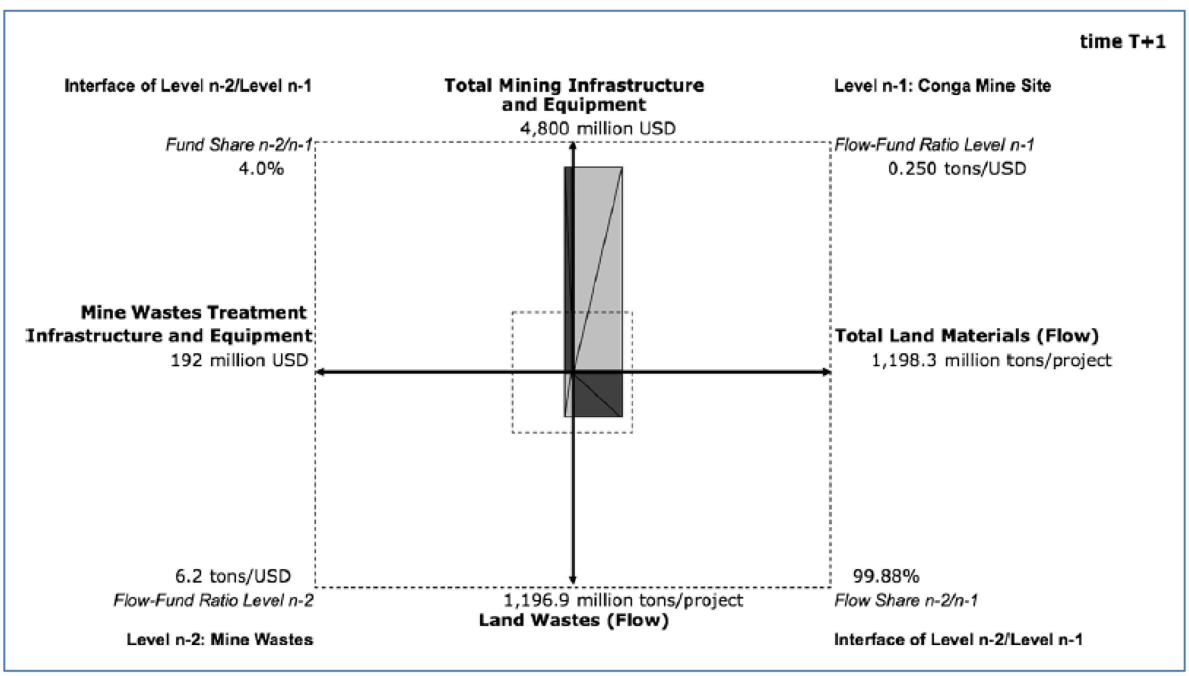
Source: Own elaboration inspired in Giampietro and Mayumi (2004)

Figure 5: Land Materials (conflict fund or flows) vs. Water Input



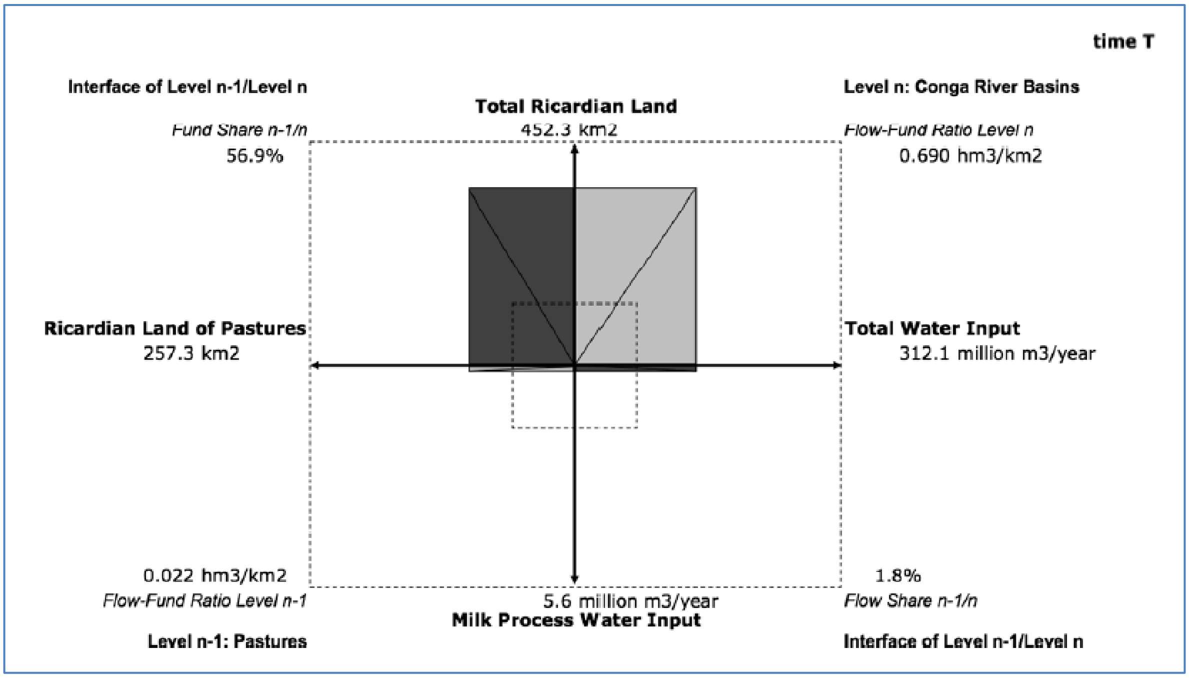
Source: Own elaboration inspired in Giampietro and Mayumi (2004)

Figure 6: Mine Infrastructure vs. Land Materials (as flows)



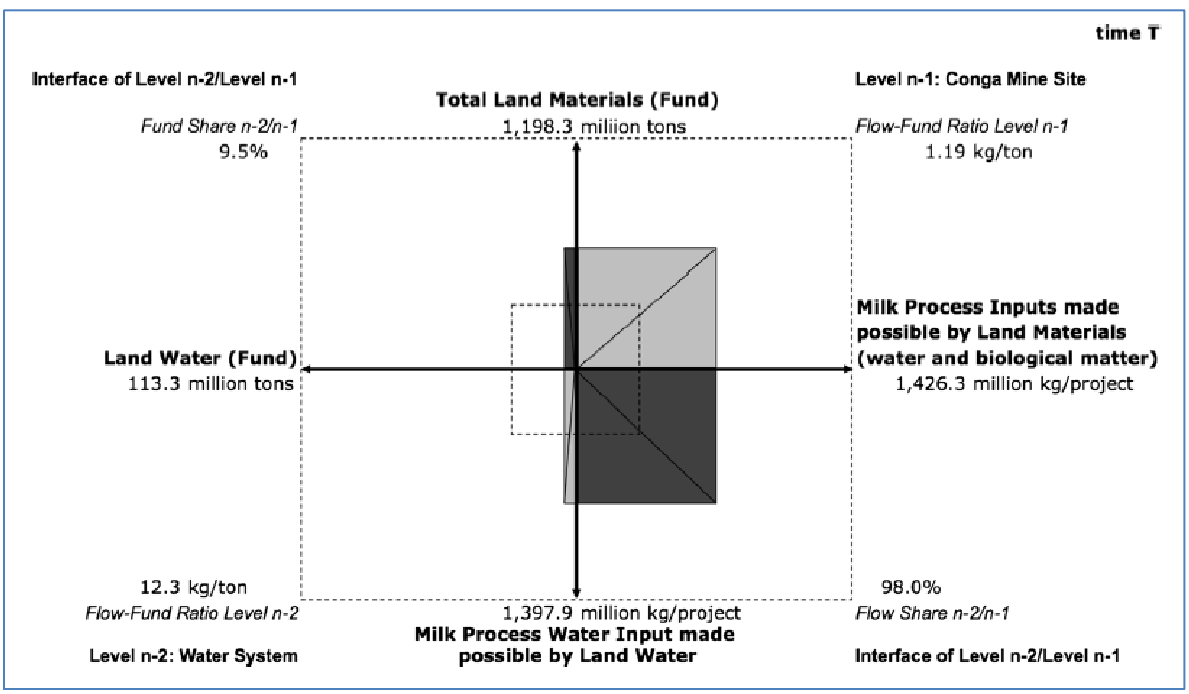
Source: Own elaboration inspired in Giampietro and Mayumi (2004)

Figure 7: Ricardian Land vs. Water Input (milk process)



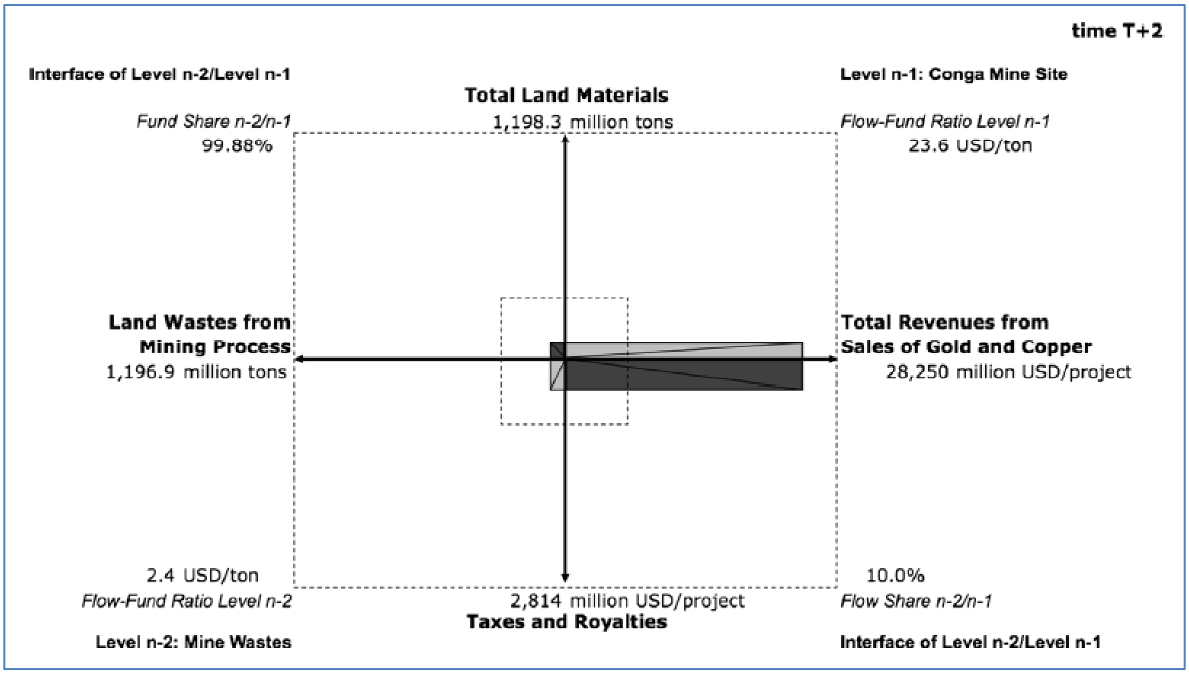
Source: Own elaboration inspired in Giampietro and Mayumi (2004)

Figure 8: Land materials (as funds) vs. Milk Process Inputs



Source: Own elaboration inspired in Giampietro and Mayumi (2004)

Figure 9: Land Wastes vs. Monetary Revenues



Source: Own elaboration inspired in Giampietro and Mayumi (2004)

5.3. Discussion

The key contradiction between land materials as fund for the campesinos, and land materials as flow for the mining company is represented in the graphs above (Fig. 5, 6 and 8). Although the Ricardian land of the mining infrastructure is unchanged and eventually returned to the community, its land material composition is irreversibly transformed. In addition, the use of hazardous substances, modification of land structure (open pits) and aggressive interventions in the water system all constitute long-term changes to the land material that is being used by campesinos as a fund. The problem of acid mine drainages, as just one example, can persist in freshwater ecosystems for more than 200 years (USGS 2000).

The results presented in the Figures 4 and 7 specify relations between the scales n/n-1 and the elements land area (fund) and water input (flow), for the two respective processes. The values employed (see Annex II) are gross estimates and would need to be calculated with much greater precision, if these data were to be used for applied, as opposed to conceptual work. Limitations aside, we can estimate that the mining process will use roughly 994,000 m3 of water per km2 of Ricardian land per year to the milk process' roughly 22,000 m3/km2. Even with a fair margin for error, we find minerals extraction to be over 40 times more intensive in annual use of water per km2 of Ricardian land. Based on reference data from the Yanacocha mine, we estimate a water flow-share (levels n-1/n) of 6.4% for the Conga mine (Fig. 4, lower right quadrant), which reflects the proportion of all water flowing through the five rivers basins, on an annual basis, that is likely to be diverted for use in the Conga mine, on an annual basis. While this number might seem reasonably low, it represents a substantial volume of displaced and potentially contaminated water, in the neighborhood of 19,000,000 m3 per annum. In addition, the water input rate, (flow-fund ratio for level n-1 Fig. 4, bottom left quadrant) of 0.994 hm3 per km2 of mining infrastructure, exceeds our estimate of the generalized input rate for the entire set of river basins (flow-fund ratio for level n Fig. 4 top right quadrant), which is only 0.690 hm3 per km2. While it is important to keep in mind that we are operating here with very rough estimates, this relationship suggests reason to be concerned about overexploitation of water resources in the immediate area around the mining infrastructure. Such overexploitation would, of course, have consequences for the quality of land materials used by campesinos as a fund.

Figures 5, 6, 7, and 8 show how the land identities of the mining company and campesinos contradict one and other at the functional level (n-1/n-2), with respect to the performance of value creation: through extraction of gold and production of milk. In Fig. 7 the MuSIASEM for milk production is presented, which reflects the first time step of our analysis – prior to the commencement of mining activities; land is represented in the Ricardian terms of km2. However, for the campesinos, not only is it necessary that Ricardian land remains unchanged (i.e. serves as a fund) but also that the living land (what we call here land materials) is maintained over time. The mining company, which has a comparatively brief relationship to the living land, during the minerals extraction process, sees land materials as a flow (Fig. 6) and there is no way to prevent this category assignment, since the irreversible transformation of these land materials is the purpose of the mining process. Juxtaposing Figures 7 and 8, where we move from a Ricardian to a land materials reference, measured in mass (millions of tons), illustrates this contradiction. Whereas we can use the same Ricardian land referent for Figures 4 and 5, the MuSIASEM representation of land materials has to be realized using two separate referents (Figures 6, 8). In this way we can see the consequences of the change in land structure, represented through juxtaposition of an estimate for the capacity of the eliminated aquifer, which we call classify as the fund 'land water' and the estimated aquifer water flow contributing to the milk production process. Whereas land materials, as a flow, are processed at a rate of 0.250 tons per USD by the mining infrastructure and equipment (Fig. 6), as a fund, the aquifer that would be eliminated through their extraction facilitates the flow of 1.19 kg of production inputs per ton of land material, 98% of which are water (Fig. 8). Presuming 1 liter of water = 1kg of water, based on Schlink et al’s (2010) estimate that 990 liters of virtual water are required to produce 1 kg of milk, we can estimate that the loss of this fund is roughly equivalent to the loss of 1,400,000 kg of milk production, over the life of the Conga project [(Fig.8 n-2 flow of 1,398 million kg of water) * (1 liter/kg) / (990 liters/kg of milk)], which will continue as a loss of roughly 80,000 kg per year in time step T+2. While these numbers are far from precise, they help to illustrate, in concrete terms, the functional concerns of the campesinos.

Turning our attention back to Fig.6, we have a flow-share rate at level n-2/n-1 (lower right quadrant), representing the proportion of extracted land materials converted into waste, of 99.88%. The balance of 1.4 million tons/project is the metals concentrate containing gold and copper. Included in land materials is the pumping out of the aquifer that forms a part of the geology of the Conga site. We estimate, based on available data, that a total of 191.5 million tons of water would be pumped out of the aquifer by the end of the project (included in the n-1 flow in Fig.6). This can be juxtaposed against an estimated rainfall infiltration, or recharge rate, for the eliminated aquifer of 78.2 million tons/project. Again, keeping in mind that these figures are very rough estimates, this represents a net loss of stored ground water on the order of roughly 113.3 million tons during the period of mining operations. While there is very limited information available regarding what consequences that this level of aquifer depletion might have for the surrounding ecosystems, the magnitude of the relationship between the two systems can be observed by juxtaposing this with the aquifer water flow required for milk production in the Conga mine site (Fig.8 n-2 flow), which we estimate to be roughly 1.4 million tons of water for the total project operations, giving a ratio of flow/fund (n-2) of 0.012. In other words, the amount of water diverted from the hydrogeological system, as a consequence of the mining operations is roughly 80 times the amount being used by campesinos for milk production.

Finally, Fig.9 shows the relationship between the land materials fund of the campesinos and the monetary revenues flow expected from the Conga mine at time step T+2, after the mining process is over. In return for the elimination of this fund the national and local governments of Peru would receive a flow-share of 10% of the total expected revenues of 28.3 billion USD. However, the flow-fund ratio at level n-2 show a rate of 2.4 USD of government income (taxes and royalties) per ton of land materials fund that has been irreversibly destroyed. As above, this does not include long-term consequences associated with potential release of hazardous substances and acid mine drainage, which could move through the water system (lakes, springs, rivers, streams, aquifers) during time step T+2, with the potential for contamination to reach as far as the Amazon River Basin (level n+1). While we have excluded these contaminants from our calculations, we hope our study helps to reinforce Castello et al.’s (2001:1) argument that “Existing management policies –

including national water legislation, community-based natural resources management schemes, and the protected area network that now epitomizes the Amazon conservation paradigm…intended to conserve terrestrial ecosystems, have design and implementation deficiencies, or fail to account for the hydrologic connectivity of freshwater ecosystems."

6. Conclusions

The Conga mine conflict analyzed in the preceding pages, between the Minera Yanacocha mining company and the local campesino population, can be understood as an archetypical example of environmental conflicts at the commodity frontier (Moore 2000; Martínez-Alier 2010[2002]). In an effort to improve understanding regarding how such conflicts, which are often violent, can be resolved or avoided, we have set out to sketch the anatomy of this conflict, using the flow/fund model developed by Georgescu-Roegen (1976[1965]; 1971) to study the relationship between two conflicting economic processes: mining and milk production. In order to do this, we employed the concept of valuation triadics (Farrell 2007), which enables us to relate the conflicting purposes of the two processes with the spatial and temporal boundaries of the respective economic processes. This step, in turn, made it possible for us to use the approach of multi-scale integrated assessment of societal and ecosystem metabolism, MuSIASEM, (Giampietro and Mayumi 2000a; 2000b; 2004; 2009), in order to represent specific flow-fund relations and conflicts between the two processes across different spatial and temporal scales.

Taking the land area of our study as the five associated river basins of the districts of La Encañada, Huasmín, and Sorochuco (level n), we distinguished between sets of elements used by Minera Yanacocha and/or the campesinos including: the mining infrastructure (level n-1) and the pastures (level n-1). In order to explore the roots of this conflict, we added to this the ambiguous element of land materials, which served to make visible the spatial overlap, during times T+1 and T+2, between the mining and milk production activities.

Then, the combination of the primary settings, or Anschauung, based on production purpose and referenced in terms of time and space were used to delimit the parameters of the respective economic processes to the specification of elements of production. Based on a detailed review of contradictions associated with the element land materials (as opposed to Ricardian land) we illustrated that the roots of this environmental conflict can be represented in terms of a conflict over the flow/fund status of the land materials designated for extraction during the mining process, which are perceived by the campesinos as a fund and by Minera Yanacocha as a flow. The MuSIASEM representations employed in this analysis allow us to organize the available empirical data in a manner that shows the magnitude of impacts that the mining process has, with respect to the milk production activities of the campesinos and highlights the fundamental place of land removal and hydrogeological disruption in this conflict.

While the results of this study are not surprising, the use of the flow/fund and MuSIASEM framing helps to reveal the concrete dynamics of the conflict, providing a complement to environmental impact assessment (EIA). By assessing how different languages of valuation conflict, on the ground, in Conga, we can see more clearly which economic factors are driving the conflict, which makes it possible to explore the question of what alternative economic processes might satisfy the interests of the actors involved. The approach also presents the possibility to assess interactions between the value systems, in terms of flows and funds, during planning stages, in a way that may help policy makers to anticipate potential environmental conflicts. With respect to the specific case studied here, our analysis suggests that solutions to this conflict might be found, for example, if more attention were paid to fact that the mining process includes the consumption of a production element (land materials) that is currently providing services for the campesinos.

Chapter IV

Exploring futures for Amazonia's Sierra del Divisor: an environmental valuation triadics approach to of analyzing ecological economic decision choices in the context of major shifts in boundary conditions

Jose Carlos Silva Macher and Katharine N. Farrell

This text presents a new methodological approach to ecological economic analysis, employing Georgescu-Roegen's flow-fund theory. It offers an alternative to monetary valuation based analyses and aims to contribute toward advancing work on ecological economic Gestalt methodologies. The methodology is demonstrated through reference to the empirical case of a proposed rail link between Peru and Brazil, which would cut across the Sierra del Divisor of western Amazonia, connecting the Pacific and Atlantic coasts and further opening up the Amazon commodity frontier. In order to analyze the potential impacts of the rail link, flow-fund representations of economic process are developed for four alternative futures, using a combination of environmental valuation triadics based representations of economic purpose and Multi-scale integrated Analysis of Societal and Ecosystem Metabolism representations of economic process. In this way we develop an impact oriented analysis of the project's potential ecological economic consequences that replaces monetary estimates of the economic contribution made by the threatened forest area with attention to the overall implications of the project for the region. Our results suggest that completion of the rail link is likely to have substantial negative consequences for forest conservation in both Peru and Brazil and for local livelihoods throughout the region.

1. Introduction

One of the core methodological challenges of ecological economics was described by Costanza, in the first issue of this journal, as follows: "the need to treat integrated economic-ecologic systems with a common (but diverse) set of conceptual and analytical tools" (Costanza, 1989: 1). While this broad methodological question received considerable attention in the early years of ecological economics, recent years show a clear trend away from integration and toward specialization (Costanza and King, 1999; Costanza et al, 2004). Methodology debates in the journal are today focused, in large part, on technical matters, sometimes with a strong ecological orientation, often as part of a discourse concerning how to estimate the real economic worth of ecological phenomena. In so far as the aims of ecological economics continue to be those articulated in the first issue of the journal, and we assume they do, this focus on components needs to be balanced with work on *Gestalt*, concerning the whole of ecological economic processes. Recalling Costanza's and Norgaard's respective appeals for methodological integration and methodological pluralism, advanced against an historical backdrop of whole-system approaches (e.g. Boulding, 1950; Georgescu-Roegen, 1971; Odum, 1971), we aim to contribute toward the ecological economics *Gestalt* level methodology discourse by presenting an innovative empirical case study of potential socio-environmental impacts associated with infrastructure expansion within the Amazon.

While we are sympathetic to the aims of both monetary valuation and ecology based approaches to ecological economics, we maintain that 'taking the environment into account' also requires tools that specifically address the methodological challenge of bridging ecological and economic analysis, supporting what Max-Neef (2005) has called strong interdisciplinarity. The new methodology we propose serves to organize study of ecological economic metabolic patterns by combining representations of systems of value articulation (Farrell, 2009[2005], 2007) and physical accounting. It is applied here to structure analysis of a set of alternative economic processes available to a set of social actors facing the possibility of major changes in the boundary conditions of a shared environmental focal point. It is intended to provide a basis for analysis and decision support by unpacking the implications of the project and can, in that respect, be understood as an alternative to the cost-benefit analyses toward which monetary valuation estimates often contribute. In order to illustrate the potential usefulness of this approach, we employ the empirical case of the proposed Transcontinental Brazil-Peru, Atlantic-Pacific railway (i.e. Ferrovía Transcontinental Brasil-Perú, Atlántico-Pacífico [FETAB], in Spanish), a large-scale ground transport infrastructure project set to run between the Atlantic port of Santos (Sao Pablo, Brazil) and the Pacific port of Bayovar (Piura, Peru). Although, the final route is not yet determined, the project (DAR, 2016), should it be realized, could include connecting the Brazilian city of Cruzeiro do Sul (Acre State) and the Peruvian city of Pucallpa (Ucayali Region). This would lay a transport link across the Sierra del Divisor, a large, still intact, region of the Amazon Forest and would effectively cut the Amazon in two. FETAB would connect Mato Grosso State, which has both the highest soybean production in Brazil (Pacheco, 2011; Salin, 2015) and a commensurately high area of deforestation (WWF, 2013) not only with Peru but also China, the world's top soybean importer (USDA, 2016). Soybean from Mato Grosso is currently shipped to Santos and from there, via the Atlantic and Indian oceans, to China. FETAB would make direct shipment via the Pacific possible. The national governments of China, Brazil, and Peru all support the project, which is expected to facilitate trade between the three countries (Global Times, 2015), reducing transportation costs for commodity exports to China, consisting of soybean and iron ore from Brazil, and minerals concentrates of copper and gold from Peru (International Business Times, 2015). While FETAB proposes a new route, to the north, in Peru, links between the Pacific coast and the city of Pucallpa are already well established. In Brazil, the city of Cruzeiro do Sul is linked by a poor but operational road to Mato Grosso, which is well linked to the Atlantic coast via a stable transport route to Santos.

In the following pages we compare the ecological economics of alternative economic processes that may arise if FETAB is built, basing our analysis not only on reference to monetary worth, real or estimated, but also on comparison of the ecological economic anatomy of alternative economic processes (Silva-Macher and Farrell, 2014). The alternatives are identified based on the likely consequence of an extreme shift in the external physical constraints (Giampietro and Mayumi, 2009) facing the actors who envision and realize these processes. While our results are highly case specific and provisional, we intend for the methodology to be more widely applicable to a broad range of similarly configured cases. Whether the radical shift is due to technological change, climate change or natural disaster, we may expect, in the short term, a combination of a comparatively steady economic purpose referents, depicted here using Farrell's (2007) concept of environmental valuation triadics, combined with a major shift in what is materially possible, traced here over space and time using a simplified version of Giampietro and Mayumi's (2000a, 2000b, 2009; Giampietro, 2003; Giampietro and Bukkens, 2015) accounting tool MuSIASEM (Multi-scale integrated Analysis of Societal and Ecosystem Metabolism).

Data from Brazil, regarding cultivation and deforestation dynamics in the region, provide a good indication of what could happen if the link is opened and data for a similar infrastructure project, the IIRSA Southern Brazil-Peru Interoceanic Highway, in Cusco, Peru, which passes through *Madre de Dios* provide a good indication of how this might play out in Peru (Asner et al., 2013). Based on these data and other sources, we develop an analytical representation of changes that could be expected in Sierra del Divisor Park area.

Our aim is neither to condemn nor to condone the FETAB project, but to use it as an empirical basis for elaborating our approach. Farrell's (2007) concept of environmental valuation triadics is developed to critique reliance on monetary estimates of the economic worth of priceless ecological phenomena, while Giampietro and Mayumi's (2000a, 2000b, 2009) MuSIASEM tool can be understood as an application of key elements of Georgescu-Roegen's (1971) flow-fund theory of economic process. By combining the two, we replace monetary estimates of the potential damage with an approach that aims to shed light on what is at stake.

The methodology allows us to systematically compare different and even incommensurable languages of valuation (Martinez-Alier, 2010[2002]) by juxtaposing functional aspects of how different valuation systems make use of a common focal object (Farrell, 2007: 23); in this case the Sierra del Divisor. We then combine the environmental valuation triadic approach with MuSIASEM, in order to develop a set of stylized representations of how completion of FETAB might impact the societal metabolism of the region: two best case alternatives, one for the soybean industry and one for the local communities, and two worst case alternatives, also one for the soybean industry and one for the local communities. All four representations share the same point of focus, the Sierra del Divisor with a transport link between Cruzeiro do Sul and Pucallpa, but each is constructed through reference to a different combination of valuation systems and boundary conditions (see Table 1). In this way, we are able to develop an analysis of the potential ecological economic implications of the project based on reference to the material ecological economic impacts it can be expected to have, while avoiding representing the economic value of the Sierra del Divisor in monetary terms.

Table 1: Four Stylized Alternatives for the Future of Sierra del Divisor

	Soybean production industry	**Local communities of Sierra del Divisor in Peru (1)**
Best case	*Alternative 1: The government promise of progress.* Increased production, increased trade to China, no forest damage.	*Alternative 3: The local communities of Sierra del Divisor continue as before.* No significant change in the structure and functions of local communities.
Worst case	*Alternative 2: Amazon land degradation.* Increased production, trade to China and in the region, expansion of soybean production in Acre, Brazil, massive forest destruction.	*Alternative 4: The local communities of Sierra del Divisor have changed into Madre de Dios II.* Radical expansion of alluvial mining, massive forest destruction and rivers contamination, significant changes in the structure and functions of local communities.

<u>Source</u>: Own elaboration based on primary and secondary data. (1) The local communities of Sierra del Divisor are subdivided in four types of economic processes: (a) the alluvial mining of some communities in the Abujao River; (b) the fishing of Calleria indigenous community; (c) the rice production of Santa Sofia farmer community; and (d) the hunting and gathering of Isconahuas indigenous people living in voluntary isolation.

2. Background and Development of the four alternative processes

Expansion of commodity frontiers in the Peruvian Amazon is favored by large-scale infrastructure projects for commodities transportation, energy generation, and water diversion that serve industrial agriculture and the energy-water-mining complex (Parker et al., 2015; Sharife and Bond, 2011). FETAB would represent a sudden opening of a new frontier in Amazonia, which can expected to facilitate first timber extraction, burning of forest, the introduction of cattle ranching, plantations of eucalyptus, soybean, and palm oil and eventually mineral extraction and hydroelectricity generation.

Severe socio-environmental conflicts are already present in other Amazon frontiers in Peru. One example is the ecological distribution conflict of *El Baguazo,* where 33 people died in 2009 in violent confrontations between the police and indigenous peoples (Defensoria del Pueblo, 2009) while protesting against new laws privatizing forest lands. Another one is the environmental and health impacts on Achuar indigenous people due to petroleum activities in Northern Peruvian Amazon (Orta et al., 2007). In addition, there are indigenous people living in voluntary isolation in the Sierra del Divisor region who would face duress if there is development of extractive industries and infrastructure. The key role played by Grupo Romero, one of the largest Peruvian finance and manufacturing conglomerates, in the establishment of palm oil plantations and associated deforestation suggests that Peru is well positioned to advance along this frontier (EJOLT, 2016b). Illegal mining and logging are also likely to follow the opening up of the transport link, as these are growing rapidly in the regions surrounding the existing IIRSA Southern Interoceanic Highway project, with severe social and environmental impacts (Valencia, 2014; Asner et al., 2013). It is equally likely that little or no measures will be taken by the Peruvian government to halt the progression. In a recent report by Global Witness (2015) Peru occupied the fifth position in the world on the number of deaths of environmentalists in 2014, mainly indigenous people.

2.1. The National Park Sierra del Divisor

The National Park Sierra del Divisor is a protected area of 1.35 million hectares located in the central Peruvian Amazon (Ucayali and Loreto regions) with the Ucayali River and Andes to the west and linked with a contiguous National Park in Brazil, to the east (MINAM, 2015). The Southern part of the Peruvian Sierra del Divisor overlaps with the Isconahua Indigenous Reserve of 275,665 hectares, inhabited by indigenous people living in voluntary isolation (MINAM, 2015; Ministerio de Cultura, 2016a, 2016b; Matorela, 2004; Chirif, 2010). Sierra del Divisor is a complex of mountains rising from the Amazon lowlands and is internationally recognized for its high concentration of rare and range-restricted biological species. A rapid biological inventory in 2006 registered over 1,000 vascular plants, 109 fishes, 109 reptiles and amphibians, 365 birds, and 38 large mammals (Vriesendorp et al., 2006). In addition, there at least 20 local communities living near the park, whose economic activities are directly dependent on the quality of land, forests and rivers that flow from its mountains. Economic processes in the local community include: fishing with nets in rivers and lakes; cultivation of rice, maize, and fruits; timber extraction; hunting and gathering and production of handcrafts. Production is mainly subsistence with some trade in Pucallpa city.

The Sierra del Divisor was classified as a National Park in November 2015, after nine years of negotiations, following classification as a Reserve Zone in April 2006. Initially, there was a dispute between conservationists, who preferred the National Park status and indigenous people organizations, who wanted exclusive rights. Eventually the National Park status was applied, with part of the area designated for the Isconahua Indigenous Reserve (Ministerio de Cultura, 2016a) in May 2016. There was also dispute between conservationists, including the Ministry of Environment, and the Ministry of Energy and Mining, which favored the conservation status of National Reserve, in order to allow extractive industries with approved environmental management plans into the area (Monteferri et al., 2009).

2.2. The Transcontinental Brazil-Peru Railway project (FETAB)

Rather than aiming to evaluate the entire FETAB project, we focus on one of the critical limiting factors for its completion: the link between the cities of Pucallpa and Cruzeiro do Sul, which would cut across the Sierra del Divisor. This part of the FETAB route provides a clear reference point, and runs alongside a Natural Park, providing means to explore a worst case scenario for the ecological impacts that might accompany completion of the project.

Plans to construct a transcontinental railway have a history in Latin America, extending back to ideas from the *caucho* (rubber) extraction period in the 1880s (Basadre, 1968). Today, the colonialist dream of overcoming the geographical obstacles of the continent is symbolized through the *Initiative for the Integration of the Regional Infrastructure of South America (IIRSA)*, which aims to development a network of highways, railways, ports, hydroelectric dams, electric grids, and hydrocarbon pipelines across the Andes-Amazon region (IIRSA, 2016). The FETAB railway project, if built, would definitively cut the Amazon rainforest in two, and, depending on the final route, could cause substantial direct damage to flora and fauna in the National Park Sierra del Divisor, as well as severe impacts in the Isconahua Indigenous Reserve (see map in Appendix; DAR, 2016). In addition, since transport infrastructure facilitates access to the forest and rivers, it would open up new opportunities for the expansion of both legal and illegal alluvial gold mining and logging, with associated deforestation. The introduction of large-scale cattle ranching and soybean production, which are established practices in the contiguous Brazilian Amazon, can also be expected to expand into the region. The IIRSA Southern Brazil-Peru Interoceanic Highway (IIRSA Sur Highway) has already been associated with severe environmental and social impacts in the south of the country, illustrating the types of impacts that can be expected in the Sierra del Divisor region.

The IIRSA Sur Highway was completed in December 2010. Since that time alluvial gold mining has increased radically along the route from Cusco to Madre de Dios and in the nearby Puno region (Valencia, 2014; Asner et al., 2013). This extractive process causes substantial direct damage to riverbeds and forest and employs hazardous substances, such as mercury, which are dispersed into the environment, seriously affecting the entire food chain, including the food of local communities. Massive deforestation has been documented, including within the surrounding area of the National Reserve Tambopata (MAAP, 2016b). While the highway is not the only factor influencing the gold boom in Madre de Dios, it facilitates the transport of extracted gold and of the work force, the machinery and fuels required for extractive activities. During 2014 the Ministry of Interior reported 165 cases of missing people and 4 homicides in the illegal mining area of La Pampa, Madre de Dios (Convoca, 2015), while a set of maps reported by the Monitoring of the Andean Amazon Project (MAAP, 2016a) show clear indications of a new deforestation hotspot along the IIRSA Sur highway.

3. Materials and Methods

While the geographical obstacles are substantial and the FETAB project may well never materialize, we take up the question of its potential ecological economic consequences as a classic decision choice problem. This allows us to illustrate how we propose to employ the environmental valuation triadics (Farrell, 2007) approach in order to present an alternative to cost-benefit analysis. In place of trying to estimate and net monetary costs/benefits implications, we compare and contrast the ecological economic anatomies of the new modes of societal metabolism that might be expected to develop in the region, in the event that FETAB were to be built.

3.1. Materials

This case study is based on a combination of primary and secondary data. Two intensive field visits were made to local rural communities surrounding the National Park Sierra del Divisor, in 2008 and 2013. Data were collected through semi-structured interviews, meetings with community leaders and villagers groups and through ethnographic observation. Three communities were visited in 2008: Betania indigenous community, which is a mixture of ethnic Shipibos and people coming from the city of Pucallpa, located 4 hours by boat from Pucallpa on the Ucayali River, on the way to the Abujao River; Flor de Ucayali, an indigenous community, mainly Shipibos, located 14 hours by boat from Pucallpa, on the Utiquinia River; and Santa Sofia, a farmers community, made up of *colonists* or peasants, who migrated from the Andes in the 1960s, also located on the Utiquinia River. During the 2013 fieldwork the Flor de Ucayali indigenous community and the Santa Sofia farmer community were revisited and the Calleria indigenous community, comprised mainly of Shipibos, located, 12 hours by boat from Pucallpa, on the Calleria River was also visited. All of these communities are located in the Ucayali region in the Central Peruvian Amazon, in close proximity to Sierra del Divisor. Secondary data include publications on the Sierra del Divisor, on the Isconahua's indigenous people living in voluntary isolation (MINAM, 2015; Ministerio de Cultura, 2016a, 2016b; Matorela, 2004; Vracko, 2014; Chirif, 2010), on soybean production in Brazil and related transportation costs (Pacheco, 2011; Salin, 2015; CONAB, 2016), and news reports on the Transcontinental Brazil-Peru Railway Project (International Business Times, 2015; Global Times, 2015; Reuters, 2015).

3.2. Methods

We use Nicholas Georgescu-Roegen's flow-fund model, as operationalized in Giampietro and Mayumi's MuSIASEM approach, to juxtapose the material flows of alternative futures for the region, in the event that the link between Pucallpa and Cruzeiro do Sul were to be built. Following Silva-Macher and Farrell (2014) and Farrell and Mayumi (2009), the temporal and spatial boundaries of alternative processes are delimited through reference to the perspectives of the actors involved (Table 2). In the present case two perspectives (i.e. soybean industry and local communities) are used to structure a total of four different representations of metabolic flows, based on the two alternatives of a best and a worst case result from completion of FETAB. The two representations for the soybean industry are simple (Tables 3a and 3b), while the two for local communities are composites of four different but tightly related representations that highlight a range of key local perspectives (Tables 4a-7b).

3.2.1. The Technique employed for Comparative Analysis of Alternative Economic Processes

We have selected an empirical case study that allows us to explore what we have called above the *Gestalt* methodological challenge of ecological economics and take the National Park Sierra del Divisor, the overlapping Isconahua Indigenous Reserve and the surrounding local communities as an analytical whole. While the full FETAB project is intended to run from Santos to Bayovar, coast to coast, we focus only on the key connection between Cruzeiro do Sul and Pucallpa.

The four plausible alternatives for how human use of this biophysical context might be transformed, due to the external shock of a large-scale technological change are compared with each other and against a business as usual baseline. The set of social actors has been selected based on two criteria: living near or within the Peruvian part of Sierra del Divisor and/or using the railway for commodities transport. The set of economic processes associated with each social actor serve here as token for the entirety of economic processes in the region (Giampietro and Bukkens, 2015). They are not intended to give a complete picture but rather to stand as place holders for the full breadth of impacts. They have been chosen based on the likely ways in which activities in the region can be expected to develop, based on reference to official government policy and reference cases, including patterns of deforestation in Brazil and the impacts of the IIRSA Sur Highway.

3.2.2. Combining Environmental Valuation Triadics with MuSIASEM

We represent the value articulation system (Farrell and Vatn, 2004; Farrell, 2009[2005]; Vatn, 2005) of each social actor group by applying Farrell's (2009[2005], 2007) concept of environmental valuation triadics. These represent social actors' value systems baselines, from which they are assumed to interpret and respond to the change in constraints implied by the building of FETAB. In the case of the soybean production industry, the baseline triadic does not include Sierra del Divisor because there is at present no ground transport connection.

Farrell's (2009[2005], 2007) concept of environmental valuation triadics depends on two underlying presumptions, both of which we use here: (1) that the process of value articulation can be usefully be described as a triadic hierarchical system (Salthe, 1985), and (2) that all articulations, or expressions, of environmental value are embedded within social and institutional contexts that influence how objects of valuation are perceived. An environmental valuation triadic can be understood as a complex representation of the process of value articulation (Farrell and Vatn, 2004; Vatn, 2005; Farrell, 2009[2005], 2007), comprised of three hierarchical levels: (1) higher (structure – value system), (2) focal (focus – perception of the object of valuation), and (3) lower (functional – articulated values). The three categories describe, respectively, the preconceptions, perspectives and actions of an actor or group of actors concerned with a given object of valuation. The focal level is the central part of the valuation triadic and reflects the way in which an actor or a range of differently positioned actors perceives a common object of valuation.

Silva-Macher and Farrell (2014; see also Farrell, 2009 [2005]) link the concept of valuation triadics to the Georgescu-Roegen's (1971) flow-fund theory of economic production by taking up a social actor's valuation triadic as a way to define the boundaries of an economic process specified at the focal level, through reference to the actor's *Anschauung* (intuition, perspective, or purposive gaze) at the structural level. Flow-fund element identities then arise as a consequence of these constraints, manifest at the functional level.

We represent the metabolic patterns of the social actors and the respective economic processes implied by their triadics of valuation using a simplified version of the MuSIASEM approach. Our intention is not to build a complete MuSIASEM, but rather to use this tool to help bridge together Farrell's (2007) concept of environmental valuation triadics with Georgescu-Roegen's flow-fund theory of economic process, based on reference to specific metabolic patterns. Key flows and funds are identified for inclusion in the analysis based on reference to the environmental valuation triadics. Flow/fund and flow/flow metabolic ratios are then calculated for each economic process. The focal level of each MuSIASEM (level n) is the economic process specific using the triadics. The upper level (n+1) reflects the social and biophysical context (i.e. environment); the lower levels (n-1) are sub-processes, expressed in terms of flow and fund elements.

The environmental valuation triadic can be understood as a further elaboration of what Giampietro (2003) and Giampietro et al. (2013) refer to as the pre-analytical step required in order to develop a MuSIASEM representation for a specified economic process. Since both the triadic and MuSIASEM are based on the logic of hierarchical systems representations, they can be linked together through the specification of focal points of attention, in spite of their being concerned with fundamentally distinct content. Since flow-fund element status depends on the boundaries of the economic process in question (Georgescu-Roegen, 1971; Mayumi, 1999; Farrell and Mayumi, 2009; Silva-Macher and Farrell, 2014) this provides us with an analytical basis for constructing representations of focal level economic processes based on MuSIASEM. The lower level of the valuation triadics is the identity of the production elements, expressed in terms of flows and funds and quantified here in keeping with the conventions usually employed in MuSIASEM representations: reporting a combination of extensive variables that define the process being represented (i.e. the magnitude of the main fund and main flow constituting the process) and intensive variables, which provide information regarding the dynamics of the process (i.e. flow/fund, flow/flow, subordinate fund share, and subordinate flow share ratios). We incorporate the large-scale technological change (in this case the FETAB railway project) by assuming changes in the material boundary conditions (i.e. environment, metabolic structure n+1) of the respective metabolic profiles constructed through reference to the respective valuation triadics, in order to compare the alternative processes.

4. Results

Having defined the methodology, the empirical case of Sierra del Divisor and the FETAB Transcontinental Brazil-Peru railway project, we are now in a position to look at the four stylized alternative processes representing how the situation in the region might develop, were the link to be established.

Alternative Process 1 (best case/ international): *The government promise of progress* – the FETAB will facilitate international trade between Peru, Brazil, and China (e.g. Mato Grosso soybean production is shipped to China, via Peru). Environmental and social impacts will be controlled via government regulations and corporate social responsibility practices. Soybean production will not expand into the states of Acre, Rondonia, and Amazonas in Brazil. Deforestation will be controlled because the railway represents superior access control, as compared with highways, while soybean companies will increase their profits due to significant transportation costs reductions.

Alternative Process 2 (worst case/ international): *Amazon land degradation* – the FETAB will generate an incentive for the expansion of the soybean frontier in the state of Acre in Brazil, considering that this region is located next to Peru, and so closer to the Bayobar port and from there, to China. Deforestation will increase radically in the Amazonia, with all the associated environmental and social impacts. Although, the railway offers better access control than a highway, socio-economic pressures (e.g. farming and towns asking for new railway stops) will increase the number of access points along the railway.

Alternative Process 3 (business as usual/ local): *The local communities of Sierra del Divisor continue as before* – the FETAB will not generate significant changes in the structure and functions of local communities living near or within the National Park Sierra del Divisor and Isconahua Indigenous Reserve. The Calleria indigenous community will continue their small-scale economic activities of fishing, farming, timber extraction, and handcraft production without deforestation and river pollution. Some local communities located to the south of Sierra del Divisor, along the Abujao River, will continue their alluvial gold mining, which generates major socio-environmental impacts in the region.

Alternative Process 4 (worst case/ local): *The local communities of Sierra del Divisor have changed into Madre de Dios II* – the FETAB will generate significant changes in the structure and functions of local communities living near or within the National Park Sierra del Divisor and Isconahua Indigenous Reserve. The railway will facilitate access to rivers for the radical expansion of alluvial gold mining activities, not only at the Abujao River, but also along the Calleria and Utiquinia Rivers, as well as inside the National Park Sierra del Divisor and Isconahua Indigenous Reserve, generating severe socio-environmental impacts, including the disappearance of the Isconahua indigenous people. The share of local human activity allocated to alluvial mining, especially among young people, will increase radically because of better income opportunities. Fishing, farming, hunting and gathering, and small-scale timber production will be seriously affected, producing major social transformations in the economic and cultural dynamics of these local communities.

4.1. Representing economic process using environmental valuation triadics

The specific social actors upon which the representations of alternatives are based, and the respective economic processes in which they are engaged, are as follows: Actor Group 1 - industrial soybean producers, soybean production process in Mato Grosso (Brazil) and the transportation sub-process moving soybean to Shanghai (China); Actor Group 2 - alluvial miners along the Abujao River (to the south of Sierra del Divisor), gold extraction process from the river's sediments; the Calleria indigenous community, small-scale fishing process and the transportation sub-process to Pucallpa; the Santa Sofia farming community, small-scale rice production process and the transportation sub-process moving rice to Pucallpa; the Isconahua indigenous people living in voluntary isolation, small-scale hunting and gathering within the Amazonia.

Table 2 summarizes the social actors' environmental valuation triadics under the baseline context, prior to construction of the railway, with the focal point consisting of their respective economic processes. The structural level of these baseline environmental valuation triadics is related to what Giampietro and Mayumi (1997: 463) call the initiating conditions (i.e. cultural identity, knowledge, technological capital and reproduction of human mass), which can also be understood as the historical momentum of the actor groups. This structural level (here called *Anschauung*) provides us with a reference point, on the basis of which it is possible to anticipate how the respective communities can be expected to respond to these changes in the short term.

Table 2: Environmental Valuation Triadics of selected Social Actor Groups – Baseline (before the construction of the Transcontinental Brazil-Peru Railway)

Social Actors	**Structure (Purpose)**	**Focus (Economic process)**	**Function (Elements identity)**
Group 1: Industrial soybean producers (Brazil) (triadic 1)	To increase the profit for the owners or/and shareholders: Costs reduction (transport of soybean grains). Sales growth (national and international).	Large-scale soybean industrial production in Mato Grosso and export to China. Very long distance to ports within Brazil. Intensive use of agrochemicals (fertilizers, pesticides, herbicides).	Funds: Farmland, infrastructure and machinery (Capital), and human activity. Flows: Fuels and electricity, agrochemicals, water, soybean grains, and wastes.
Group 2: Alluvial miners in the Abujao River (triadic 2)	To increase the profit for the owners: Cost reduction (transport of workers, machinery, and supplies). Sales growth (including black markets).	Gold mining extraction from river's sediments using mercury.	Funds: Land and rivers, machinery (Capital), and human activity. Flows: Fuels (diesel), mercury, gold, and wastes.
Group 2: Calleria indigenous community (triadic 3)	Supply of endosomatic energy for the local community. And, Sell the fish in the city of Pucallpa for money required to buy other supplies.	Small-scale fishing with nets in the Calleria River.	Funds: River with healthy fish, human activity, and boats, nets, and coolers. Flows: Fuels for the boats, ice for the coolers, and fish.
Group 2: Santa Sofia farmer community (triadic 4)	Supply of endosomatic energy for the local community. And, sell the rice in the city of Pucallpa for money required to buy other supplies.	Small-scale rice production with minimum use of agrochemicals.	Funds: Farmland, human activity, animals (plow), and boats (transport). Flows: Fuels for the boats, fertilizers, and rice.
Group 2: Isconahua indigenous people in voluntary isolation (triadic 5)	Supply of endosomatic energy for the local community.	Small-scale hunting and gathering activities within the 275,665 hectares of the Isconahua Indigenous Reserve (overlapped with the National Park Sierra del Divisor).	Funds: Forest land and rivers, human activity, tools (e.g. bow and arrow, pots). Flows: Collected vegetables, and hunted animals.

Source: (1) Pacheco (2011), Salin (2015); (2) Vracko (2014), Alvarez et al. (2011); (3) Fieldwork in Sierra del Divisor (2008, 2013); and (4) Matorela (2004).

Having these triadic structures in mind, we next focus on the description of associated economic processes related to the potentially impacted region. Tables 3, 4, 5, 6 and 7 summarize the simplified MuSIASEM representations for the metabolic patterns associated with each economic process, first before (a) and then after (b) construction of the railway.

4.2. Combining the valuation triadics approach with simplified MuSIASEM

4.2.1. Industrial Soybean Producers in Brazil, the Soybean Production process and the Transport sub-process to China

The following quantification of flows and fund is based on data for year 2014:

Production and exports: Total soybean production in Brazil was of 86.7 million tons; and soybean production in Mato Grosso was of 26.4 million tons. Total soybean exports from Brazil were of 46.7 million tons; soybean exports from Brazil to China were of 32.6 million tons; and soybean exports from Mato Grosso to China were of 9.1 million tons (Salin, 2015).

Transportation from Mato Grosso to China: By truck – the average distance between Mato Grosso (Brazil) and the port of Santos is of 1,600 km (Pacheco, 2011). By sea – the distance between the port of Santos and the port of Shanghai (China) is of 20,300 km, via the Atlantic and Indian oceans; and the distance from the port of Bayovar (in the North of Peru) to the port of Shanghai is of 16,500 km (SeeRates, 2016). A rough estimate of 3,000 km average distance between Mato Grosso and the port of Bayobar, across the Sierra del Divisor.

Costs of transportation and soybean prices: Based on Salin's (2015) data for year 2014, we presume transportation costs from Mato Grosso to Shanghai, via the port of Santos to be 140.75 US$ per ton of soybean, divided between two modes of transport: by truck, 103.90 US$/ton; and by ocean, 36.85 US$/ton. The soybean farm price in Mato Grosso, also taken from Salin (2014) is presumed to be 388.33 US$/ton, giving a total provision cost, for delivery to China, of 529.08 US$/ton. The costs of transportation are related to the fuel consumption, which depends strongly on the distance, the quality of the transport route, load weight, environmental conditions, the type and quality of vehicles, and finally also on port services and the container space optimization for achieving maximum load. The costs of rail transport in Brazil are slightly less than for truck transport.

Table 3a: Industrial Soybean Production Process (Brazil) - Baseline

Spatial scale	Ratios Before FETAB	Funds Before FETAB	Flows Before FETAB
Environment (n+1)	Flow/Fund ratio: 2.88 tons of soybean per hectare (in Brazil)	Farmland for soybean in Brazil: 30.1 million hectares	86.7 million tons of soybean grains produced in Brazil per year
Main process (n)	Flow share (n/n+1): 30.45% Flow/Fund ratio: 2.97 tons of soybean per hectare (in Mato Grosso)	Farmland for soybean in Mato Grosso: 8.9 million hectares	26.4 million tons of soybean grains produced in Mato Grosso per year
Sub-process (n-1)	Transport costs index, that is, the cost of shipping a metric ton of soybeans 100km: By truck: 6.49 US$ By sea: 0.18 US$	Transport from Mato Grosso to China, via port of Santos: By truck: 1,600 km By sea: 20,300 km	Product: 9.1 million tons of soybean grains of exports from Mato Grosso to China per year Transport costs: By truck: 103.90 US$/ton By sea: 36.85 US$/ton Total: 140.75 US$/ton

Table 3b: Industrial Soybean Production Process (Brazil) - Best and Worst Cases

Spatial scale	Starting with the same Ratios	Funds After FETAB	Flows After FETAB
Sub-process (n-1) **Best Case**	Transport costs index: By railway: 6.49 US$ (Then, it has to be reduced in >43% in order to be viable) By sea: 0.18 US$	Transport from Mato Grosso to China, via Peru: By railway: 3,000 km By sea: 16,500 km	Transport costs: By railway:194.7 US$/ton By sea: 29.7 US$/ton Total: 224.4 US$/ton
Sub-process (n-1) **Worst Case**	Transport costs index: By railway: 6.49 US$ By sea: 0.18 US$	Transport from Acre to China, via Peru: By railway: 1,000 km By sea: 16,500 km	Transport costs: By railway: 64.9 US$/ton By sea: 29.7 US$/ton Total: 94.6 US$/ton

Source: Own elaboration based on Salin (2015); Pacheco (2011); SeeRates (2016).

4.2.2. Local Communities involved in Alluvial Mining, Fishing, Farming and Hunting and Gathering

<u>Alluvial Mining along the Abujao River and Gold Extraction in Amazonia</u>

The Ministry of Energy and Mining (MINEM, 2016) classifies alluvial mining in Peru in two categories: (1) artisanal mining (<1,000 hectares of concession size with <25 tons/day of productive capacity; < 200m3/day of extracted sediments); and (2) small mining (<2,000 hectares with <350 tons/day; <3000 m3/day respectively) using heavy machinery (e.g. dredges, loaders, and trucks). Environmental impacts include deforestation and contamination of rivers with mercury and hydrocarbons. Deforestation in the Madre de Dios region, due to alluvial mining, is estimated at 32,000 hectares, including natural protected areas (Alvarez et al., 2011). The number of alluvial mining workers estimated to be active in Madre de Dios is 30,000 people. They extract between 16,000 and 18,000 kg of gold per year. This provides us with a very rough estimate of 0.57 kg of gold/year per mining worker (working 2,190 hours/year) and an associated estimated use of 2.8 kg of mercury per kg of extracted gold (Alvarez et al., 2011). The total land area of legal mining concessions in the Madre de Dios is 34,100 hectares (Alvarez et al., 2011). Along the Abujao River the total land area of legal alluvial mining concessions is 7,400 hectares (Vracko, 2014).

Table 4a: Alluvial Miners (Gold) operating in the Abujao River - Baseline

Spatial scale	Ratios Before FETAB	Funds Before FETAB	Flows Before FETAB
Environment (n+1)		Forestland and rivers with potential gold content. Transport by barges of workers, heavy machinery, and supplies (13 hours by boat from Pucallpa). Mining concessions land area in the Abujao River: 7,400 hectares.	Deforestation (output flow of forestland biomass): 2,000 hectares (alluvial mining in the Abujao River started in 1984).
Main process (n)	<u>Flow/Fund ratio</u>: 0.26 grams of gold per hour of human activity in alluvial mining.	Human activity in alluvial mining: 300,000 hours/year (137 miners).	<u>Product</u>: 78 kg of gold extracted per year.
Sub-process (n-1)	<u>Flow/Flow ratio</u>: 2.8 kg of mercury per kg of gold extracted.	Gold-Mercury amalgamation	280 kg of mercury used per year.

Table 4b: Alluvial Miners (Gold) operating in the Abujao River – Best and Worst Cases

Spatial scale	Starting with the same Ratios	Funds After FETAB	Flows After FETAB
Main process (n) **Business as usual**	0.26 grams of gold per hour of human activity in alluvial mining.	Human activity in alluvial mining: 330,700 hours/year (151 miners)	86 kg of gold extracted per year (10% growth).
Main process (n) **Worst case**	0.26 grams of gold per hour of human activity in alluvial mining.	Human activity in alluvial mining: 898,000 hours/year (410 miners)	234 kg of gold extracted per year (200% growth).

Source: Own elaboration based on Vracko (2014) and Alvarez et al. (2011)

The Calleria Indigenous Community and Fishing

Based on data collected during field studies in the community, the following data is used to quantify flows and funds for the fishing activities of the Calleria Indigenous Community, located along the Calleria River.

Human Activity: There are 10 boats in the community, each operated by two workers. There are 20 fishermen who work an average of 35 hours per week, without vacations, in fishing and trading with the city of Pucallpa, giving the estimate of 20 fishermen* 35hours/week* 52weeks/year = 36,400 hours/year of human activity dedicated to fishing.

Production: The average fish capture (considering dry and rainy seasons combined), with nets, is 25 kg/day per boat. This gives 25 kg/day-boat *3days/week *10boats *52weeks per year = 39,000 kg/year of fish. They used to fish 3 days per week for own consumption, at a rate of 20% dedicated to subsistence and 80% to trade.

Transport: Each journey to Pucallpa uses 10 gallons of gasoline per boat (12 hour journey) with a load of 300 kg of fish (net weight). Trade = 31,200 kg/year (80% of total production). Roughly 104 journeys per year are required to transport the fish to Pucallpa (31,200/300). The boats return with supplies from the city, giving an additional 104 journeys. Total gasoline use for trading is estimated at 2,080 gallons/year.

Table 5a: Small-scale Fishing with nets in the Calleria River - Baseline

Spatial scale	Ratios Before FETAB	Funds Before FETAB	Flows Before FETAB
Environment (n+1)		Calleria River starts in the Sierra del Divisor mountains with enough fishes (free of toxics) for the native community. Population: 330 people. Land area: 4,035 hectares.	Food Requirement: 49,800 kg/year of biomass (based on a diet of 5 kcal/gram of biomass mix for 43% children; 51% adults; and 6% elderly).
Main process (n)	Flow/Fund ratio: 1 kg of fish /hour of human activity in fishing.	Family Boats made of wood: 10 units. Human activity in fishing: 36,400 hours/year	Product: Fish: 39,000 kg/year. 80% trade. 20% self-consumption.
Sub-process (n-1)	Flow/Flow ratio: 15 kg of fish /gallon of gasoline.	Transport to Pucallpa Distance: 12 hours by boat (one way).	Use of fossil fuels: 2,080 gallons of gasoline per year.

Table 5b: Small-scale Fishing with nets in the Calleria River – Best and Worst Cases

Spatial scale	Starting with the same Ratios	Funds After FETAB	Flows After FETAB
Main process (n) **Business as usual**	1 kg of fish /hour of human activity in fishing.	Human activity in fishing: 36,400 hours/year (20 fishermen)	Fish: 39,000 kg/year (steady-state)
Main process (n) **Worst case**	1 kg of fish /hour of human activity in fishing.	Human activity in fishing: 18,200 hours/year (10 fishermen)	Fish: 19,500 kg/year (50% decline due to river pollution)

Source: Own elaboration based on the Fieldwork of 2013.

The Santa Sofia Farming Community and Rice Production

Based on data collected during field studies in the Santa Sofia community, the following data is considered for the quantification of flows and funds for the rice production process of this farmer community, located along the Utiquinia River.

Population and Land area: The Santa Sofia farming community population is estimated in 182 people (40% children; 40% adults; 20% elderly). One third of the adults, 24 people, work in rice production and trading, on average for 20 hours per week, giving 24 workers*20 hours/week-worker*52 weeks = 24,960 hours of human activity in rice production per year. The land area of Santa Sofia is of 60 hectares with land area allocated to rice production of 15 hectares.

Production: The productivity rate of rice in the Ucayali region is on average of 2.4 tons/ha, which is considerably lower than the national average rate of 7.6 ton/ha and well below the rate of La Libertad region (on the coast) of 11.5 ton/ha. Rice production in Santa Sofia is characterized by a minimum use of agrochemicals and based on animal power; there is no heavy machinery available in these areas of the Amazon, which are located far away from urban centers.

Trade: They use 2 days per week (1 day there and 1 day to return) for trading with Pucallpa, with a maximum load of 600 kg of cereals. Each boat travel 104 times (=2x52 weeks) per year with each journey (to and from Pucallpa) requiring a total of roughly 11.7 gallons of gasoline, giving a total of 1,216.8 gallons of gasoline/year per boat.

Table 6a: Small-scale Rice Production in the Utiquinia River (Santa Sofia) - Baseline

Spatial scale	Ratios Before FETAB	Funds Before FETAB	Flows Before FETAB
Environment (n+1)		Santa Sofia community land area: 60 hectares. Total population: 182 people (40% children; 40% adults; 20% elderly).	Food requirement: 27,900 kg/year of biomass (based on a diet of 5 kcal/ gram of biomass mix; and age distribution).
Main process (n)	Flow/Fund ratios: 2,400 kg of rice/ hectare. 1.44 kg of rice/ hour of human activity in rice production.	Land area used in rice production: 15 hectares. Human activity in rice production: 24,960 hours/year.	Product: Rice: 36,000 kg/year 80% trade 20% self-consumption
Sub-process (n-1)	Flow/Flow ratio: 24 kg of rice /gallon of gasoline.	Transport to Pucallpa Distance: 14 hours by boat (one way).	Fuels: 1,217 gallons of gasoline /year.

Table 6b: Small-scale Rice Production in the Utiquinia River (Santa Sofia) – Best and Worst Cases

Spatial scale	Starting with the same Ratios	Funds After FETAB	Flows After FETAB
Main process (n) **Business as usual**	1.44 kg of rice/ hour of human activity in rice production.	Human activity in rice production: 24,960 hours/year (24 farmers)	Product: Rice: 36,000 kg/year (steady-state)
Main process (n) **Worst case**	1.44 kg of rice/ hour of human activity in rice production.	Human activity in rice production: 5,200 hours per year (5 farmers). (80% decline due to alluvial mining demand).	Product: Rice:7,490 kg/year (Almost the same value allocated for community self-consumption).

Source: Own elaboration based on the Fieldwork 2013.

Isconahua Indigenous People and Hunting and Gathering

Data concerning the Isconahua are based on reference literature.

The estimated population is of 170 people (Chirif, 2010) and we assume a population distribution of 40% children; 40% adults; and 20% elderly (half women; half men). The men are specialized in hunting (and fishing) while the women are specialized in gathering. Production techniques are taught from parents to children until the initiation ceremony when they become adults (Ministerio de Cultura, 2016b). The Isconahua Indigenous Reserve has a total land area of 275,665 hectares.

Nutrition: 170 people (68 children eating 1500 kcal/day; 68 adults eating 2500 kcal/day; and 34 elderly eating 2500 kcal/day) are estimate to have a dietary requirement of 357,000 kcal per day. Assuming 5 kcal/gram of food biomass mix, we estimate 71,400 grams of biomass per day are required for feeding all the Isconahua. Bearing in mind that Isconahua are mostly nomads, they consume what they hunt and gather without stocking biomass. On this basis we assume a minimum requirement for daily hunting and gathering 71,400 grams of biomass/day.

Human Activity: 68 adults gives 68x24 hours = 1632 hours of total human activity per day which we assume to be distributed between 50% physiological overhead, 25% for hunting and gathering and 25% for teaching children and leisure. This gives 1632x25% = 408 hours of hunting and gathering per day for food provision.

Table 7a: Isconahua Indigenous People in Voluntary Isolation and Hunting and Gathering processes in the Amazon Rainforest - Baseline

Spatial scale	Ratios Before FETAB	Funds Before FETAB	Flows Before FETAB
Environment (n+1)	Fund Share of adults: 25% hunting and gathering 25% leisure and education 50% physiological overhead.	Forestland area (Isconahua Indigenous Reserve): 275,665 hectares. Population: 170 people (40% children; 40% adults; 20% elderly).	Minimum daily food intake of the total population: 71,400 grams of food biomass per day.
Main process (n)	Flow/Fund ratio: 175 grams of biomass per hour of human activity in hunting and gathering.	Human activity in hunting and gathering: 408 hours/day.	Product: 71,400 grams of food biomass hunted and gathered per day.
Sub-process (n-1)	140 grams of animals/ hour of hunting 210 grams of vegetables/ hour of gathering	Human activity in hunting: 204 hours/day. Human activity in gathering: 204 hours/day.	Animals: 28,500 g/day Vegetables: 42,900 g/day

Table 7b: Isconahua Indigenous People in Voluntary Isolation and Hunting and Gathering processes in the Amazon Rainforest – Worst and Best Cases

Spatial scale	Ratios After FETAB	Funds After FETAB	Staring with the same Flows
Main process (n) **Business as usual**	Flow/Fund ratio: 175 grams of biomass per hour of human activity in hunting and gathering. (Steady-State)	Human activity in hunting and gathering: 408 hours/day. (25% hunting and gathering; 25% children education and leisure; 50% physiological overhead).	Product: 71,400 grams of food biomass hunted and gathered per day.
Main process (n) **Worst case**	Flow/Fund ratio: 87.5 grams of biomass per hour of human activity in hunting and gathering. (50% reduction in the animal population and vegetables due to deforestation and other environmental pressures).	Human activity in hunting and gathering: 816 hours/day. (50% hunting and gathering; 5% children education and leisure; 45% physiological overhead).	Product: 71,400 grams of food biomass hunted and gathered per day.

Source: Own elaboration based on Matorela (2004); Chirif (2010); and Ministerio de Cultura (2016b).

5. Discussion

Based on the simplified MuSIASEM representations presented above, we are in a position to compare the ecological economic implications of the four stylized alternatives. This analysis aims to evaluate, in a non-monetary but nonetheless partially quantitative manner, the possible consequences of FETAB for the economic processes of the respective social actors. The focus is on how changes in the boundary conditions affect the functioning of each economic process. Critical flow and fund elements are taken here as tokens (Giampietro et al., 2013; Giampietro and Bukkens, 2015), which provide indicative information regarding how the processes might change. Based on the results presented above, we discuss here, by way of comparisons within and across the two social actor groups, what changes might be expected in their respective economic processes.

Industrial Soybean Producers in Brazil and Transport sub-process to China

Taking first the best case, we have a new route for shipping soybean grains from Mato Gross production sites to China, via Peru. That is, a new sub-process (level n-1) of 3,000 km transport by railway crossing the Andes and 16,500 km transport by the Pacific Ocean. If we assume the same technical coefficients (i.e. transport cost index [the cost of shipping a metric ton of soybean 100km], see Table 2), then, the cost of shipping a metric ton of soybean from Mato Grosso to China, via Peru, will be of 224.4 US$/ton: the sum of land (railway) transport (6.49 US$ x 3000km/100km = 194.7 US$/ton) plus ocean transport (0.18 US$ x 16500km/100km = 29.7 US$/ton). Comparing this with the baseline value of 140.75 US$/ton (103.9 US$/ton by truck plus 36.8 US$/ton by ocean), it does not seem plausible that this best case alternative will be realized unless there is a radical reduction in land transport costs, which is, considering the geography of the Andes-Amazon region, unlikely.

Alternative Process 2 (worst case) is a more likely outcome when considering costs and taking into account the geography of the region. It implies the expansion of the soybean frontier within the State of Acre, with associated Amazon deforestation. Here there would be a land transport costs saving of 129.8 US$/ton, in the event that shipping between Sorriso (Mato Grosso State) and Cruzeiro do Sul (Acre State), which are separated by around 2,000 km, were to be replaced by production closer to the railway link. The cost of shipping a metric ton of soybean from Acre to China is estimated at 94.6 US$/ton, which is of 33% cheaper than the baseline value of 140.75 US$/ton for shipping from Mato Grosso to China, via Santos.

Alluvial Miners in Abujao River and Gold Extraction process

If the railway is constructed, alluvial mining can be expected to expand radically in the Sierra del Divisor (worst case). This is supported by the evidence on IIRSA Sur Highway in the Cusco region of Madre de Dios (see Section 2.2). Favorable boundary conditions for transportation of workers, machinery, supplies, and products are afforded by the railway connection, as it is safer and faster to transport heavy machinery by rail than by barge. Alluvial mining expansion would imply additional human activity in mining, the impacts of which we calculate by assuming growth of 200% in the sector in the region, with human activity rising from 300,000 hours/year to 898,000 hours/year, based on an increase labor force, from 137 to 410 miners. We assume rates of expansion similar to those seen in Madre de Dios and adjust for the smaller area suitable for alluvial mining in Abujao. Again, based on what has been seen in Madre de Dios, it can be expected that many small-farmers (i.e. part of the 73 adults active in Santa Sofia community), mainly young males, would migrate to the towns and concessions areas because of income opportunities, with impacts seen not only there but also in the economic processes of farming communities.

Calleria Indigenous Community and Fishing process

For the Calleria Indigenous Community, in the best case scenario, the baseline before the Railway (Table 2), we have categorized the land of Sierra del Divisor as a fund, to be maintained (or conserved) across time, without major disturbance from alluvial mining, due to good access control. We assume that the livelihood of the indigenous community, based on fishing and other direct provisioning human activities would be maintained.

After the technological change (the rail link), it is unlikely that the Calleria community would be directly impacted by expansion of the soybean frontier in Acre, as they are located well up river and far from the direct transport route. However, their baseline metabolic profile could well be impacted by expansion of alluvial mining operating along the Abujao River, if this expands to the North, into the Calleria River area. It is considered unlikely that outmigration of young people would be a problem, as there is a strong commitment to territory.

The worst case implies a radical increase of alluvial mining in Sierra del Divisor (legal and illegal). The boundary condition of good ecological quality in the Calleria River could be seriously impacted due to mercury and hydrocarbons pollution from alluvial mining. This would reduce the fish population, affecting the fishing process and the quality of fish capture (i.e. contaminated food).

Santa Sofia Farmer Community and Rice Production process

For the community of Santa Sofia, the Alternative Process 4 (worst case) implies outmigration of youth, due to radical expansion of alluvial mining. Considering that the viability of rice production is quite limited in Santa Sofia, due to the high transport costs and low land productivity, it is likely that farmers from Santa Sofia, especially young people, would move to the alluvial mining camps, as has been seen in the Madre de Dios region. Rice production in Santa Sofia, which depends on only 24 workers in the baseline, would be seriously impacted due to reduced availability of labor. In the medium term, a viscous cycle of migration might develop, as migrants with increased incomes incentivize other Santa Sofia residents to move into mining, eventually making rice production and other agriculture activities impossible.

Isconahua Indigenous People in Voluntary Isolation and Hunting and Gathering process

For the *Isconahua* community, the impacts of the Alternative Process 4 (worst case) are most clearly visible with regard to their consequences for human activity. Time allocated to food provision, leisure, and education, are all critical for the economic processes of the community. Under the baseline metabolic profile adults of this community are assumed to invest 25% of their time in hunting and gathering. If the construction of the railway leads to Alternative Process 2 (Amazonian land deforestation due to soybean frontier expansion) or Alternative Process 4 (Local forest and rivers are damaged due to expansion of alluvial mining and deforestation in Sierra del Divisor), it is expected that available animals, fruits and vegetables would be reduced dramatically. This change in the boundary conditions would change the internal characteristics of this hunting and gathering process. The flow/fund ratio of grams of animals biomass per hour of human time in hunting would, for example, be dramatically reduced (we assume by some 50%). Hunters would have to allocate twice the time to achieve the minimum requirement for nutrition or calorie intake would drop. If time spent providing food is doubled, there would be no time available for educating children, for example, threatening the future sustainability of the entire socioeconomic system.

These data and the associated analysis provide rough indicators of the potential consequences of alternative possible futures in a world where the FETAB project is realized. They are based on a highly stylized representation of the case and could be critiqued on specific points at a number of stages. The results nonetheless provide a clear and quantitatively substantiated picture of the project's potential ecological economic consequences. While it is not possible to state unequivocally, based on this analysis, that the link is or is not "worth the price paid," this environmental valuation triadics based approach provides indications that the price will be high, in both ecological and economic terms, both for the region and for the people living with in it.

6. Conclusions

The empirical research and methodological approach presented here uses the concept of environmental valuation triadics (Farrell, 2007) as the basis for replacing monetary cost-benefit oriented assessment of the potential consequences of alternative futures with a new methodology. Complementing earlier work from Silva-Macher and Farrell (2014), we link analysis of alternative futures to specific economic processes that have direct and/or indirect implications for the complex whole of ecological economic processes in the study region of Sierra del Divisor, in the Peruvian Amazon. A series of comparative representations are developed and analyzed in order to juxtapose likely consequences for four alternative sets of economic processes that might be expected to come into being following the construction of a rail link between the Peruvian city of Pucallpa and the Brazilian city of Cruzeiro de Sul, connecting exiting easterly and westerly routes from the Amazon, to the Pacific and Atlantic oceans, respectively.

Using the concept of environmental valuation triadics, the economic purpose of two representative groups of economic actors – the soybean industry and local communities – are specified. These are then employed to structure flow-fund (Georgescu-Roegen, 1971) based analytical representations of the economic processes in which the actors are engaged, using a simplified version of Giampietro and Mayumi's (2000a; 2000b; 2009) MuSIASEM tool. The rail link is understood to constitute a change in context (e.g. the biophysical environment) which has consequences for the internal structure and associated functions (e.g. sub-processes, element identities) of the economic processes (present and future) being represented. Possible future metabolic values are calculated based on reference to available data on encoding variables (i.e. flows, funds, and ratios), which are used to predict the likely composition of new economic processes, based on reference to changed boundary conditions.

The work provides an innovative application of Georgescu-Roegen's (1971) flow-fund theory, where the triadic representations describe a specific economic process (focal level) in relation to its intentional context (triadic structural level) in terms of flows and funds (functional level) and initial material conditions (MuSIASEM structural level). While a related approach has been demonstrated to be useful for representing the anatomy of zero sum conflicts (Silva-Macher and Farrell, 2014), between, for example open pit gold mining (Conga mountain as flow) and pastureland based milk production (Conga mountain as a fund), we propose here the methodological advance of using Georgescu-Roegen's flow-fund theory to evaluate the ecological economic implications of alternative futures.

These triadic based readings provide an impact oriented analysis that does not rely on monetary estimates of the economic contribution made by the threatened forest area but nonetheless affords ecological economic assessment of the comparative costs of alternative possible futures. Critical production elements and sub-process are represented using data on flows, funds, flow/fund and flow/flow ratios, and fund and flow shares, allowing us to anticipate impacts that may arise as the result of a major shift in the boundary conditions of the processes being represented. In the case studied here, these come in the form of technological change associated with the construction of the FETAB Transcontinental Brazil-Peru Railway. Competing economic processes and associated potential social conflicts are explored with reference to how they are likely to play out within the spatial and temporal boundaries of existing economic processes and the associated elements identities within which they arise. In this way the environmental valuation triadic approach uses quantitative representations of economic process in order to postulate regarding the likely ecological economic anatomy (Silva-Macher and Farrell, 2014) of possible futures, thereby providing a concrete alternative basis for supporting decision making regarding the ecological economic impacts of external shocks and planned changes to economic processes.

Chapter V

Conclusions

The thesis is a compilation of three scientific articles to explore the social metabolism at the commodity frontiers of Peru. The study is based on the flow/fund theory of economic production (Georgescu-Roegen, 1971), which is used to represent specific economic processes related to ecological distribution conflicts described in each case study. That is, how environmental conflicts arise both on the *funds* and the *flows* of an economy. The first and second scientific articles analyze the metabolism of the energy-water-mining complex in Peru: (1) Camisea and the electricity flows of the national mining sector; and (2) Conga and the gold mine conflict in the Andes. And, the third scientific article analyzes the metabolism of different economic processes before and after a potential large-scale transport infrastructure development: (3) Sierra del Divisor and the transcontinental Brazil-Peru railway project in Amazonia. The empirical results of these three case studies contribute to answer the general research question of the thesis by describing the anatomy of socio-environmental conflicts between local communities (e.g. *campesinos* in Conga or indigenous people in Sierra del Divisor) and public/private corporations that extract raw materials (i.e. biomass, minerals, and fossil fuels) for the global industrial society. The next sections summarize the main contributions, conclusions, and potential future research common to the three case studies.

Summary of conclusions and contributions to the study of social metabolism at the commodity frontiers of Peru

<u>Case study of Camisea</u>

The empirical results found for the national economy between years 2000 and 2010 (*level n* of the MuSIASEM) show: (1) a massive increase in size of the national energy system, which is explained by exploitation of the Camisea natural gas reserves, starting in 2004; (2) Peru is found to have an extremely low rate of exosomatic energy consumption per hour of human activity (EMR), with a societal average of only 3.1 MJ/h in 2010, as compared with industrialized countries averages in the range of 30-40 MJ/h; (3) there are growing exports of Camisea natural gas, not only directly in the form of liquefied natural gas, but also indirectly through the metals exports that used electricity during their extraction process, partially generated with natural gas; and (4) there is a potential carbon lock-in in the electricity sector due to increasing construction of electricity plants, based on the primary energy sources of the limited stock of Camisea natural gas.

In addition, the empirical results for the mining sector between year 2000 and 2010 (*level n-3* of the MuSIASEM) indicate: (1) a relatively small increase of energy input flows into the mining sector, which is explained not by energy savings but for a shift in energy carriers, that is, from low quality oil products used to generate electricity inside the mine sites to high quality electricity generated outside the mine sites; (2) the extremely high electricity metabolic rate (eEMR) of the mining sector (62 MJ/h in 2010), was found to be 11 times the rate of electricity used per hour of human activity in the building and manufacturing sector in Peru; and (3) the projection for year 2020 is a potential increase in the proportion of electricity used by the mining sector (i.e. the flow share at the interface of *levels n-3/n*). It could reduce the availability of high quality primary energy supplies for the rest of Peruvian society. Therefore, in order to maintain the national energy system operating well in the long-term, based on the present structural changes taking place, it will be necessary to ensure a sufficient supply of natural gas in the future. This implies increasing incentives for hydrocarbons exploration and exploitation activities in the Amazonia, which would have direct impacts on biodiversity and indigenous people; or increasing dependence on expensive energy imports.

Finally, in the light of these implications, the Peruvian government strong support for growth of the mining sector may have to be reconsidered. Taking up this challenge requires that decision-makers in Peru give more attention to relationships between the economy and the environment, that is, to understand the social metabolism.

<u>Case study of the Conga</u>

The ecological distribution conflict between Yanacocha mining company and *campesinos* can be represented in terms of a conflict over the identity of the *land materials* in the Conga site. From the perspective of the mining company the *land materials* are input flows of its minerals extraction process, while from the perspective of *campesinos* the same *land materials* are funds of their milk production process. Also, the MuSIASEM representations employed in this analysis allow us to organize the available empirical data in a manner that shows the magnitude of impacts that the mining process has, with respect to the milk production activities of the *campesinos* and highlights the fundamental place of land removal and hydrogeological disruption in this conflict.

The use of the flow/fund theory and the MuSIASEM analytical representations applied in this case study, help to reveal the concrete dynamics of socio-environmental conflicts, providing a complement to environmental impact assessment (EIA), which is the legal requirement for the evaluation of new mining projects in the country and a document that is the center of many scientific and political debates.

Case study of the Sierra del Divisor

The potential construction of the transcontinental Brazil-Peru railway that could cross the Sierra del Divisor represents a major change in the boundary conditions of the related economic processes. In relation to the international scale, that is, the industrial process of soybean production in Brazil and distribution to China, after the construction of the railway, the preliminary metabolic patterns analysis show that deforestation in the State of Acre (in Brazil, border of Peru) could radically increase (i.e. the worst case) due to lower transportation costs as a consequence of this possible sudden opening of this Amazon frontier by the railway.

In relation to the local scale, that is, the economic processes of local rural communities living near or within the Sierra del Divisor, we have different social actors: (1) Calleria native community; (2) Santa Sofia farmer community; (3) Isconahua indigenous people living in voluntary isolation; and (4) Alluvial miners in the Abujao River (to the South of Sierra del Divisor). For instance, we analyze that the change in the boundary conditions due to the transcontinental railway favors the alluvial miners, who will find a railway more convenient than a barge for transporting their workers, machinery, supplies, and products (including black markets). Then, it is possible a radical increase of the alluvial gold mining (legal and illegal) similar to the case of Madre de Dios and IIRSA South Interoceanic Highway (via Cusco and Madre de Dios).

This potential change of the biophysical environment could have consequences on the economic processes of the rest of social actors living in Sierra del Divisor. For instance, the preliminary metabolic patterns analysis of the hunting and gathering process of Isconahuas is illustrative. The adults of this indigenous community have to invest 25% of their human time in hunting and gathering activities in order to supply the food required by the whole community. If the railway is built, deforestation and environmental pressure could radically increase due to alluvial gold mining and the expansion of the industrial soybean production. Then, it can be expected that the number of animals and vegetables would be reduced dramatically in the Isconahuas territories. That is, the flow/fund ratio of grams of food per hour of human time in hunting and gathering would be dramatically reduced – assume a 50% reduction. Therefore, the adults would have to allocate the double of human time in order to maintain the minimum food requirement of the community, including the adults themselves. And, this would reduce significantly the adults´ human time allocated for education of children, which could threaten the sustainability of the entire socio-economic system considering that next generation will not know how to hunt animals or gather safe food in the Amazon rainforest.

Summary of conceptual and methodological contributions to ecological economics

General conceptual and methodological contribution

The general conceptual and methodological contribution to ecological economics is the development of an empirical technique to study the anatomy of ecological distribution conflicts (Martinez-Alier, 2010) at the commodity frontiers based on the flow/fund model (Georgescu-Roegen, 1971; Farrell and Mayumi, 2009). This technique combines two theoretical approaches: the environmental valuation triadics based representations of *economic purpose* (Farrell, 2007) and the multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM) representations of *economic process* (Giampietro and Mayumi, 2000a, 2000b, 2009). That is, the social actor's environmental valuation triadic is used to define the boundaries (i.e. frontier and duration) of an economic process, which can be understood as the pre-analytical step required for a MuSIASEM representation of a specified economic process.

The case study of Camisea and the energy-water-mining complex applies this technique considering as *economic purpose* the strong support of the national government to the rapid growth of the mining sector in the country, which is related to the *economic processes* that produces the new infrastructure of the national energy system. That is, the increasing electricity generation based on the limited stock of Camisea natural gas. And, this is related to the potential conflicts between the mining sector and the rest of society over the limited energy carriers, as well as the increasing pressure on the commodity frontier of the Amazonia due to hydrocarbons exploration and exploitation activities. The case study of Conga and the gold mine conflict in the Andes applies this technique for zero/one alternative economic processes. That is, the gold-copper extraction process of the mining company that perceives the Conga Mountain as an input flow versus the milk production process of the campesinos that perceives, in the opposite side, the same Conga Mountain as a fund. In other way, the case study of Sierra del Divisor and the transcontinental Brazil-Peru railway in the Amazonia applies this technique for multiple scenarios of economic processes. That is, the economic processes before and after the hypothetical construction of the transcontinental railway crossing the Sierra del Divisor, considering worst and best cases for the industrial soybean producers and the local communities. Then, if the railway is built, the preliminary results indicate that the sudden opening of this new commodity frontier can expand the industrial soybean production in the State of Acre and the radical increase of alluvial gold mine extraction with severe socio-environmental impacts on the local communities of Sierra del Divisor (i.e. the hunting and gathering process of Isconahuas indigenous people living in voluntary isolation; the fishing process of Calleria indigenous community; and the rice production process of Santa Sofia farmers community).

Particular conceptual and methodological contributions

The first particular conceptual and methodological contribution includes the analytical representation of the metabolism of the *energy-water-mining complex* for resource-rich countries. This concept is applied in the case study of Camisea (Chapter II). For instance, the MuSIASEM application was useful to understand the implications on the availability of Camisea natural gas for the rest of society (i.e. households, building and manufacturing, agriculture, and services and government) due to the government-supported growth of the mining sector in Peru. Also, this analytical representation of the national energy-water-mining complex was useful to visualize the potential carbon lock-in of the electricity generation and the possible pressure on biodiversity and indigenous people living in voluntary isolation in the Lower Urubamba River in the Amazonia due to increasing natural gas exploration. This particular analytical representation of the interdependent energy flows in the mining and energy sectors (see Fig. 2 in Chapter II) can be useful to make predictions about how the system will develop, based on how the flow/fund relationships are changing over time. For example, the construction of new electricity generation *funds* that are based on fossil energy *flows* creates dependence, which can be expected to favor, in future, new exploration and exploitation of fossil energy in the minerals resource-rich country or more energy imports.

The second particular conceptual and methodological contribution comprises the concept of *land materials*, which is used as complement of the indestructible fund of *Ricardian land*. This concept is applied in the case study of Conga (Chapter III). For instance, the MuSIASEM representation of the *land materials* of Conga Mountain (i.e. rocks, soil, and water) depend on the social actor's economic purpose, if it is the mining company the land materials are input flows of the minerals extraction process; but, if it is the *campesinos* the land materials are funds of the milk production process. The *land materials* are measured in weight units (e.g. million tons) while the related *Ricardian land* is measured in area units (e.g. hectares). The concept of *land materials* can be useful for the analysis of economic processes that imply irreversible changes in a biophysical environment (e.g. mountains, agriculture lands, forests, and surface waters), which can be initially described (or located) using the concept of Ricardian land. These destructive processes are typically the minerals extraction or the large-scale infrastructure developments, which identify these "environments" as *flow* elements. Therefore, they are in conflict with those social actors that use the same biophysical environments as *fund* elements, such as *campesinos* and their agriculture and livestock processes located in mountains or agriculture lands; and indigenous people and their fishing, hunting and gathering processes located in forests or surface waters.

Outlook for future research

Further research concerning alternatives for transitioning to the use of renewable energy, as well as into the potential impacts of changes in patterns of production and consumption is recommend, in order to identify ways to escape the carbon lock-in that appears to be awaiting the electricity sector. In order to conduct such research, MuSIASEM analysis of energy flows in the household sector (e.g. urban and rural, and across geographical regions) would also be required and are recommended as a follow-up to the present study.

The empirical methodological approach developed in the present thesis can be expanded and applied in territorial planning, which can be useful for the prevention of ecological distribution conflicts at the commodity frontiers. The approach presents the possibility to assess interactions between the value systems, in terms of flows and funds, during planning stages, in a way that may help policy makers to anticipate potential socio-environmental conflicts.

Finally, it is recommended the study of metabolic profile alternatives to the economy of extractivism in Peru and similar resource-rich countries. For instance, it can be explored possible strategies for post-extractivism in relation to the diversification of economic production and sustainability.

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Annexes

A. General map of Peru.
B. Map of geographical regions of Peru.
C. Locations of case studies.
D. Map of protected areas and communal lands in Peru.
E. Map of a possible route of the Transcontinental Brazil-Peru Railway crossing the Sierra del Divisor.

Annex A

General map of Peru

Map No. 3838 Rev. 3 UNITED NATIONS
May 2004

Department of Peacekeeping Operations
Cartographic Section

Annex B

Map of geographical regions of Peru


REPUBLICA PERUANA
OFICINA NACIONAL DE EVALUACION DE RECURSOS NATURALES
ONERN
AGENCIA PARA EL DESARROLLO INTERNACIONAL
AID
MAPA DEL PERFIL AMBIENTAL DEL PERU
1986
ESCALA 1:2'000,000
ECUADOR
COLOMBIA
BRASIL
BOLIVIA
CHILE
OCEANO PACIFICO
TUMBES
PIURA
LAMBAYEQUE
CAJAMARCA
AMAZONAS
LORETO
LA LIBERTAD
SAN MARTIN
ANCASH
HUANUCO
PASCO
UCAYALI
LIMA
JUNIN
MADRE DE DIOS
HUANCAVELICA
AYACUCHO
CUSCO
APURIMAC
PUNO
ICA
AREQUIPA
MOQUEGUA
TACNA
AREAS NATURALES PROTEGIDAS
OTROS SISTEMAS DE MANEJO DE RECURSOS NATURALES RENOVABLES
CONDICIONES MEDIO AMBIENTALES DEL TERRITORIO PERUANO
FENOMENOS NATURALES
FUENTES DE CONTAMINACION
PRINCIPALES IMPACTOS SOBRE EL MEDIO AMBIENTE
EQUIVALENCIAS GEOGRAFICAS
ISRIC - WAGENINGEN

Annex C

Locations of case studies

Studies of Social Metabolism at the Commodity Frontiers of Peru

Cases studies

- Sierra del Divisor
- Conga
- Camisea

Annex D

Map of protected areas and communal lands in Peru

TIERRAS COMUNALES Y ÁREAS NATURALES PROTEGIDAS DEL PERÚ

Incluye información de la Amazonía de Bolivia, Brasil, Colombia y Ecuador

LEYENDA

- ▲ Comunidad nativa inscrita por titular
- ● Comunidad nativa por inscribir y titular
- ■ Comunidad ribereña por titular
- Comunidad nativa demarcada y titulada
- Solicitud de titulación y ampliación
- Reserva territorial creada
- Reserva territorial propuesta
- Comunidad campesina (solo 44% con información gráfica)
- Área natural protegida
- Área de conservación regional

TIPO DE COMUNIDAD	TOTAL COMUNIDADES	TOTAL INSCRITAS	TITULADAS		NO TITULADAS		
			INSCRITAS	ÁREA TITULADA HAS.	INSCRITAS	NO INSCRITAS	ÁREA POR TITULAR HAS.
Comunidad Campesina							
Originaria - costa, sierra	6,120	6,120	5,097	23 779,801	1023	0	4 772,756
Ribereña - Amazonía	2,400	110	44	304,962	66	2,290	16 329,436
Comunidad Nativa	2,009	1,934	1,365	12 159,400	569	75	5 736,752
TOTAL	**10,529**	**8,124**	**6,506**	**36 244,163**	**1,658**	**2,365**	**26 838,828**

Total área de superficie del Perú	128,521,620 hectáreas	100%
Total área titulada a comunidades campesinas y nativas	36,244,163 hectáreas	28.2%
Total área en posesión (por titular) de comunidades campesinas y nativas	26,838,828 hectáreas	20.9%
Total área titulada y en posesión de comunidades campesinas y nativas	63,082,991 hectáreas	49.1%
Total área de bosque del Perú	73,000,000 hectáreas	100%
Total área de bosque en comunidades nativas	17,896,152 hectáreas	24.5%
Total área de bosque en comunidades campesinas (ribereñas)	16,634,398 hectáreas	22.8%
Total área de bosque en comunidades nativas y campesinas (ribereñas)	34,530,550 hectáreas	47.3%

TIERRAS COMUNALES Y ÁREAS NATURALES PROTEGIDAS

2016

SÍMBOLOS UTILIZADOS

- Capital de país
- Capital departamental
- Centro poblado principal
- Límite internacional (referencial)
- Río

FUENTES

-Comunidades nativa y ribereña georreferenciadas en campo: SICNA, con información de ACPC, AIDESEP-CIPTA, CEDIA, IBC y PETT-Loreto, 2016; Comunidades indígenas georreferenciadas en gabinete: AIDESEP-CIPTA, GEF/PNUD, GOREL y PFS, 2016
-Comunidades campesinas: COFOPRI, 2010; MINCU, 2015; GOREL, 2015
-Reservas territoriales: expedientes AIDESEP y CEDIA
-Propuestas de reservas territoriales: AIDESEP-CIPTA, FENACOCA e IBC
-Áreas naturales protegidas: Servicio Nacional de Áreas Naturales Protegidas por el Estado (SERNANP), 2015
-Límite internacional referencial: Instituto Nacional de Estadística e Informática (INEI), 2010
-Océano y relieve: World Physical Map, Source U.S. National Park Service, in ArcGis Online Services

Los datos de Bolivia, Brasil, Colombia y Ecuador utilizados en este mapa fueron facilitados en el ámbito de: RAISG - Red Amazónica de Información Sociambiental Georreferenciada

TERRITORIOS SEGUROS para las COMUNIDADES DEL PERÚ

Con el apoyo de:

RIGHTS + RESOURCES

INSTITUTO DEL BIEN COMÚN

SISTEMA DE INFORMACIÓN SOBRE COMUNIDADES NATIVAS DE LA AMAZONÍA PERUANA (SICNA)

SISTEMA DE INFORMACIÓN SOBRE COMUNIDADES CAMPESINAS DEL PERÚ (SICCAM)

Elaborado por Carla Soria
Abril 2016

Av. Salaverry 818 - Jesús María, Lima 11, Perú / Teléfonos: 332-6088, 332-6112 / csoria@ibcperu.org / www.ibcperu.org

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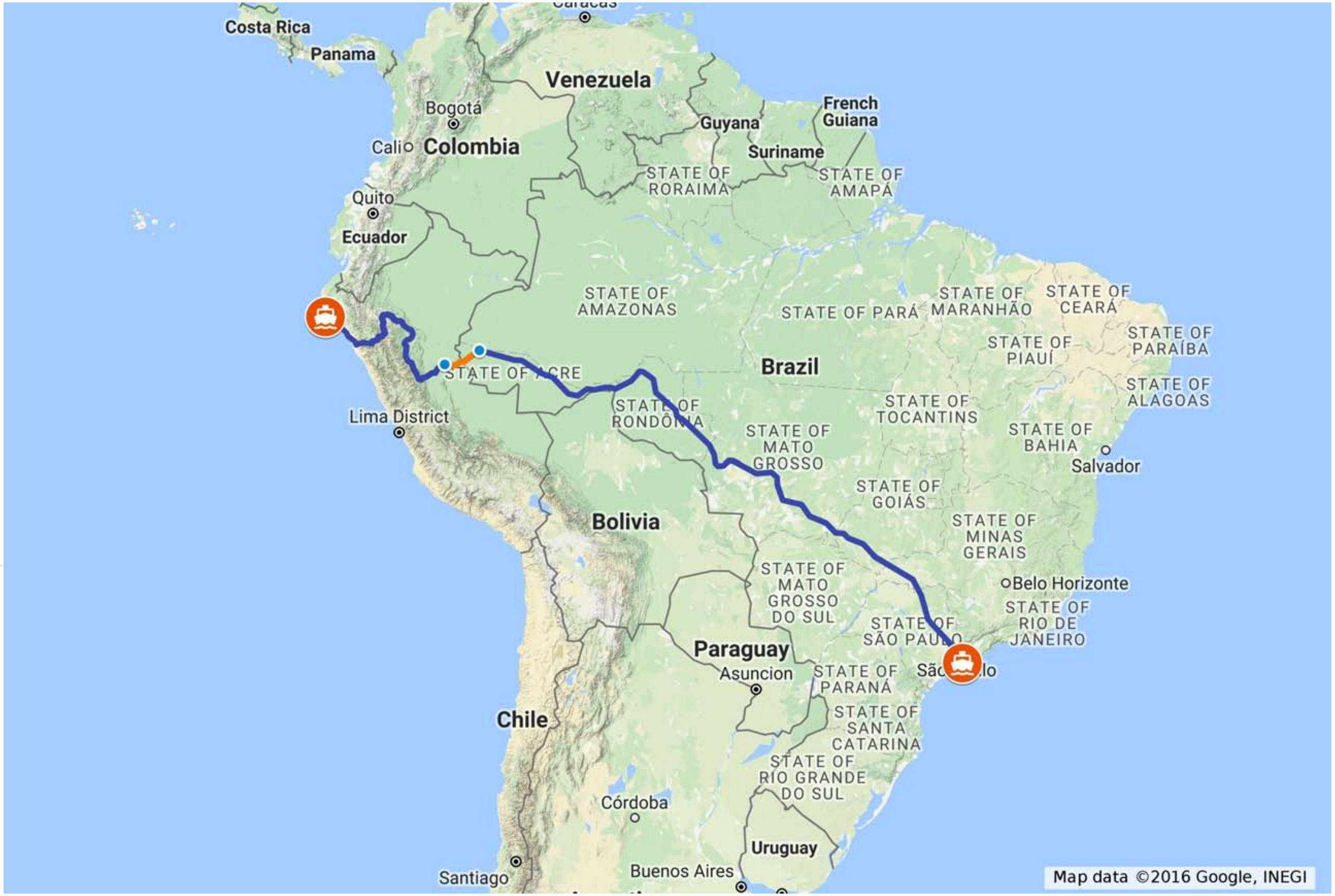
Annex E

Map of a possible route of the Transcontinental Brazil-Peru Railway crossing the Sierra del Divisor

Possible Route - Transcontinental Brazil-Peru Railway - Crossing the Sierra del Divisor

Possible Railway Route

- Port of Santos - Cuiabá
- Cuiabá - Rio Branco
- Rio Branco - Cruzeiro do Sul
- Cruzeiro do Sul - Pucallpa
- Pucallpa - Juanji
- Juanji - Moyobamba
- Moyobamba - Cajamarca
- Cajamarca - Port of Bayóvar
- Cruzeiro do Sul city
- Pucallpa city
- Port of Santos
- Port of Bayóvar



Possible Route - Transcontinental Brazil-Peru Railway - Crossing the Sierra del Divisor

Possible Railway Route

- Port of Santos - Cuiabá
- Cuiabá - Rio Branco
- Rio Branco - Cruzeiro do Sul
- Cruzeiro do Sul - Pucallpa
- Pucallpa - Juanji
- Juanji - Moyobamba
- Moyobamba - Cajamarca
- Cajamarca - Port of Bayóvar
- Cruzeiro do Sul city
- Pucallpa city
- Port of Santos
- Port of Bayóvar