Chapter 4

Mexican Rural Communities' Metabolism and Its Impact on Socioeconomic Indicators

Aida Huerta Barrientos, Alma Elia Vera Morales and Tania Vázquez González

Additional information is available at the end of the chapter

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Abstract

The rural poverty in Mexico is mainly due to the lack of access to basic services, resources, technology, and scientific knowledge. Despite the Mexican government´s efforts to contribute on improving income levels and employment in rural communities, the challenge that faces the communities to achieve sustainable development is very significant. The principal purpose of the study is to analyze the metabolic scaling of cultural, environmental, and economic aspects in the context of Mexican rural communities in order to predict the energy necessary to maintain them connected and to estimate their impact on the improvement of socio-economic indicators. First, we used the socio-metabolic approach to the study of social complex systems in rural context. The social metabolism approach aims at the study of the material and energy exchange relationships between societies and their natural environment. Then, we analyzed the metabolic scaling of cultural, environmental, and economic aspects in the context of Mexican rural communities. Finally, the energy necessary to maintain the community connected and its impact on the socio-economic indicators was evaluated. We consider that results from this study can support the design of public policies focused on the improving the living conditions of Mexican rural communities.

Keywords: culture, socioeconomic indicators, metabolism, rural communities.

1. Introduction

In 2010, rural population in Mexico was around 25 million and 61% of people were living below the national rural poverty line [1]. The main factors that influence the state of poverty in Mexico are mainly the geographical area and proximity to urban centers, ethnicity, and gender. Following [1], the incidence of rural poverty is highest in areas that are geographically located far from urban centers. Also, the poverty rate in indigenous communities is above compared to that in nonindigenous communities. In 2011, 75% of indigenous people in the country (5.6 million) were living below the poverty line. For instance, in Oaxaca, Chiapas, and Guerrero states, extreme poverty affects more than half of the population, 1.9, 1.7, and 1.7 million, respectively. The rural poverty in Mexico is due mainly by the poor access to basic services such as health, education, sanitation, housing, and resources such as land, technology, and scientific knowledge. The Mexican public expenditure in food is highly progressive, education expenditure is moderately progressive, expenditure on health is practically neutral, while public resources exercised in economic welfare and social security are regressive [2]. Although there are several federal states with processes of assessment, it is necessary to have a greater contribution at municipal and local governmental levels in the process of transparency on the use of public resources [2].

Despite the Mexican government's efforts to contribute on improving income levels and employment in rural communities, the challenges that face such communities to achieve sustainable development are very significant. For instance, rural women are now playing an active participation in socioeconomic and political decision-making not just in their own communities (local level) but also at the national level. One case comes from the indigenous communities called *Zapatistas*. On August 10, 2017, the barrios and tribes from Chiapas formed the National Indigenous Congress, so the *Zapatistas* by first time will subscribe the name of their partner María de Jesús Patricio Martínez in the 2018 electoral elections as candidate for the Mexican presidentship [3].

On the other hand, one tangible initiative of the Mexican government to contribute on improving income levels and employment in rural communities has been the National Network for Sustainable Rural Development (RENDRUS), currently managed by the Agriculture, Livestock, Rural Development, Fishery and Food Secretariat (SAGARPA). This network was created in 1996, through the action of Colegio de Postgraduados, the W.K. Kellogg Foundation, and the Rural Development Sub-Secretariat, to promote a series of annual meetings for exchanging and evaluating of experiences between rural producers, seeking a process of self-learning, at local, regional, and national levels, which would have a specific impact on Mexican rural development [4] (**Figure 1**).

The decision-making in rural communities every day face unpredictable situations that change over time, formed by complex systems of problems. Due to their inherent complexity, Mexican rural areas which are problematic cannot be studied using traditional approaches of science. Therefore, it is necessary to use modern science tools based on the complex systems approach whose methodological framework is complexity sciences that are derived from the different perspectives of the concept of complexity [5]. But what do we mean by complexity? As a background, we will begin by explaining that in the mid-40s of the last century, a group of prominent scientists from different fields such as Ross Ashby, Heinz von Foerster, Kurt Lewin, Margaret Mead, John von Neuman, Arturo Rosenblueth, Norbert Wiener, Claude Shannon, Talcott Parsons, among others, held academic meetings called Macy Conferences, taking place in New York. The purpose pursued by scientists with these lectures was to establish the foundations of a general science in the work of the human mind. This

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Figure 1. Annual meeting RENDRUS 2016.

was how they carried out the first interdisciplinary studies in Systems Theory, Cybernetics, and Cognitive Sciences. This fact was the basis of what was known as the complexity sciences. At the same time, the first classification of complexity came from Warren Weaver in his article, Science and Complexity, which was published after World War II in 1948 [6]. From the complexity perspective, rural communities can be conceptualized as complex adaptive systems because they are composed of interrelated elements such as local people and organizations that generate information and whose interactions are based on simple rules (i.e., social norms). Rural communities as complex adaptive systems are characterized by heterogeneity, interconnectivity, scaling, circular causality, and development as follows:

- Heterogeneity: diversity of people and organizations based on cultural aspects (**Figure 2**).
- Interconnectivity: everything is connected forming social networks.
- Scaling: rural communities of different sizes have different problems.
- Circular causality: cause and effect are mixed.

- Development: rural communities as systems change in open-ended ways exchanging information, material, and energy with the complex environment (**Figure 3**).
- Adaptability: people and organizations adapt to new interrelations in order to face the complex environment and its uncertainty.

As [7] states, space, time, and infrastructure play a fundamental role in enabling social interactions in allowing them to become open-ended in terms of increased connectivity and sustainable from the point of view of energy use, such interactions imply cost of people, material, energy, and information flows through decentralized networks of infrastructure that are built gradually (in some cases slowly) as the geographical zone grows. In this direction, rural communities to achieve their full socioeconomic potential communities first need to expand their social connectivity per person.

In analogy to the metabolism of biological organisms, the term "social metabolism" was coined by claiming that any social system not only reproduces itself culturally, by communication, but also biophysically through a continuous energetic and material exchange with the natural environment and eventually with other social systems [8–11]. As Fischer-Kowalski et al. suggest, social metabolism can be quantified in terms of energetic and material flows per time period,

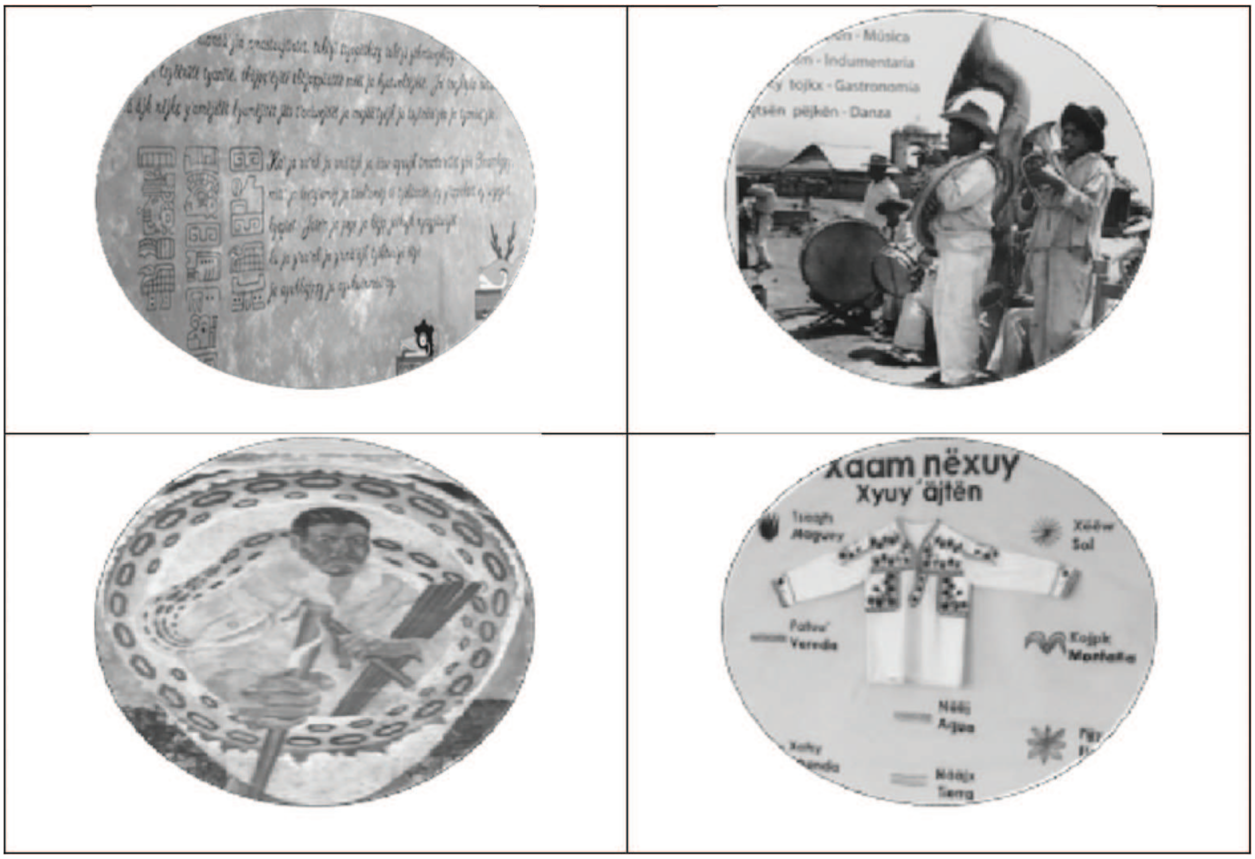

Figure 2. Cultural aspects of a Mixe community in Oaxaca Mexico.

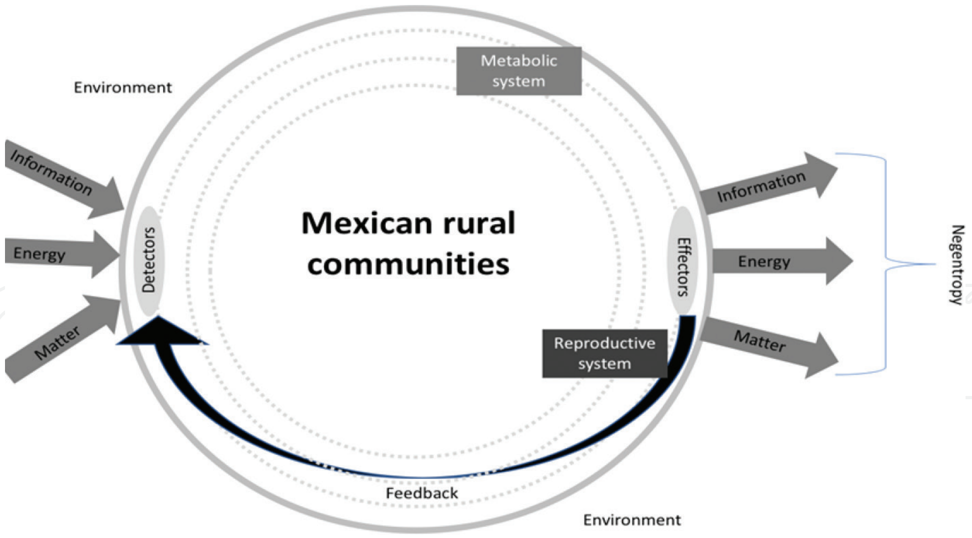

Figure 3. Conceptual model of rural communities as complex adaptive systems.

usually a year, where the size of the flows required depends on the size of the biophysical structures (stocks) of the social system and on the socio-metabolic regime [11]. The key to distinguishing a socio-metabolic regimen is the source of energy used and the main technologies of energy conversion [12]. In this direction, the socio-metabolic regimes are very dynamic and are constituted by a set of opportunities and constraints within which certain dynamics take place [11].

The social metabolism recognizes that economic resource use, the material composition, and the sources of the output flows are historically variable and they are a function of the socio-economic production and consumption system [13]. It is important to note that the socio-metabolic approach shares with the complex systems approach the notion of emergence and self-organizing dynamics. At present, little is known about applying the complexity and the socio-metabolic perspectives to analyze the socioeconomic development of rural communities, specifically in the context of Mexico. The principal purpose of the study is to analyze the metabolic scaling of cultural, environmental, and economic aspects in the context of Mexican rural communities in order to predict the energy necessary to maintain them connected and estimate their impact on the improvement of socioeconomic development. We consider the results from this study can support the design of better public policies focus on the improving the living conditions of Mexican rural communities. Here, we considered that indigenous communities are geographically embedded in rural areas of Mexican territory, so they contribute to achieve the sustainable rural development.

The chapter is divided into five main sections. In Section 2, the socio-metabolic approach applied to the study of social complex systems in rural context is reviewed. In Section 3, the analysis of the metabolic scaling of cultural, environmental, and economic aspects in the context of Mexican rural communities is presented. The energy necessary to maintain the community connected and its impact on the socioeconomic development is evaluated in Section 4. The concluding remarks are drawn in Section 5.

2. The socio-metabolic approach applied to the study of social complex systems in rural environment

On the one hand, as stated in [11], half of the world's population still lives in rural areas and it relies on subsistence farming, gathering, hunting, and fishing to survive. Following [11], the dominant development model for rural areas is still the eventual industrialization of their farming, appearing to be the only chance to reduce the high rates of poverty, health problems, and illiteracy levels. On the other hand, the sustainable development (SD) is a process of change in which the exploitation of resources, the direction of investment, the orientation of technological development, and institutional change are made consistent with future as well as present needs [14]. In this context, in September 2015, world leaders adopted the United Nations 2030 Agenda for SD, which is a universal plan of action for people, planet, and prosperity containing 17 new comprehensive, far-reaching, and people-centered SD goals: (1) end poverty, (2) end hunger, (3) ensure healthy lives, (4) ensure inclusive and equitable quality education, (5) achieve gender equality, (6) ensure sustainable management of water, (7) ensure access to energy, (8) promote sustainable economic growth, full and productive employment, and decent work for all, (9) built resilient infrastructure, (10) reduce inequality, (11) make cities sustainable, (12) ensure sustainable consumption and production patterns, (13) take urgent action to combat climate change, (14) conserve and sustainably use marine resources, (15) protect, restore, and promote sustainable use of terrestrial ecosystems, (16) promote pace and include societies for sustainable development, and last but not the least, (17) strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

In the rural context, nowadays, traditional knowledge plays an integral role in achieving SD goals, as the practices and knowledge developed by rural communities implicitly endorse practices of conservation and sustainable use of biodiversity and natural resources [15]. Millions of rural communities have used their traditional knowledge over the last 10,000 years to ensure food and livelihood security in a wide range of ecosystems throughout the domestication of plants and animals and the development of agriculture [16].

Historically, the socioeconomic and ecological complex systems have been coupled through direct input and output flows (e.g., land use) and indirect effects, such as the availability and quality of other ecosystems services or the changes in atmospheric conditions. The land use intensification, for example, denotes increase in socioeconomic inputs to and/or outputs from land and thus closely refers to socioeconomic material or energy flows [17]. A theoretical approach that aims at improving our understanding of the interactions between socioeconomic and ecological complex systems in rural environment has been adopted from the biology and it is known as the *metabolism*. According to [18], the application of the biological concept of *metabolism* to complex social systems can be traced back to Marx who talks about the *metabolism* between man and nature as mediated by the labor process, such analogy grew from the observation that biological systems and complex socioeconomic systems depend on a continuous throughput of energy and materials to maintain their internal structure. The social metabolism perspective helps us to understand the dynamic of complex social systems in terms of energy and material flows per period of time. As [11] explains, the size of the flows required depends, on the one hand, on the size of the biophysical structures (or stocks) of the complex social system (i.e., all human-made infrastructures), and on the other hand, on the socio-metabolic regime.

Associated with the concept of social metabolism, we find the notion of socio-metabolic transition to describe fundamental changes in socioeconomic energy and material use along the history. In some cases, such transitions have implied the multiplication of metabolic rates, for instance, the transition from agrarian toward an industrial society. In other cases, socio-metabolic transitions have implied the emancipation of the energy systems from land use. For instance, the transition from a solar energy system tapping into renewable flows of biomass toward a fossil-fuel-powered energy system based on the exploitation of large stocks of energy resources [19]. One interesting study about the potential use of social metabolism perspective to study the industrialization of the agriculture is presented in [20]. In this study, the information about how the socio-ecological transition took place in agriculture is analyzed.

The socioeconomic metabolism conceptualizes society as a hybrid of the complex cultural system of recursive communication and biophysical structures such as the human population, artifacts, and livestock [21] (**Figure 4**). Therefore, interactions between nature and culture can only proceed indirectly via the biophysical structure of society. Different socio-metabolic regimes have different metabolic profiles that can be expressed as total quantities for a complex social system and they can be referred to the number of the human populations the complex social system sustain and are calculated as metabolic rates (in terms of energy or material required per person per year) [11].

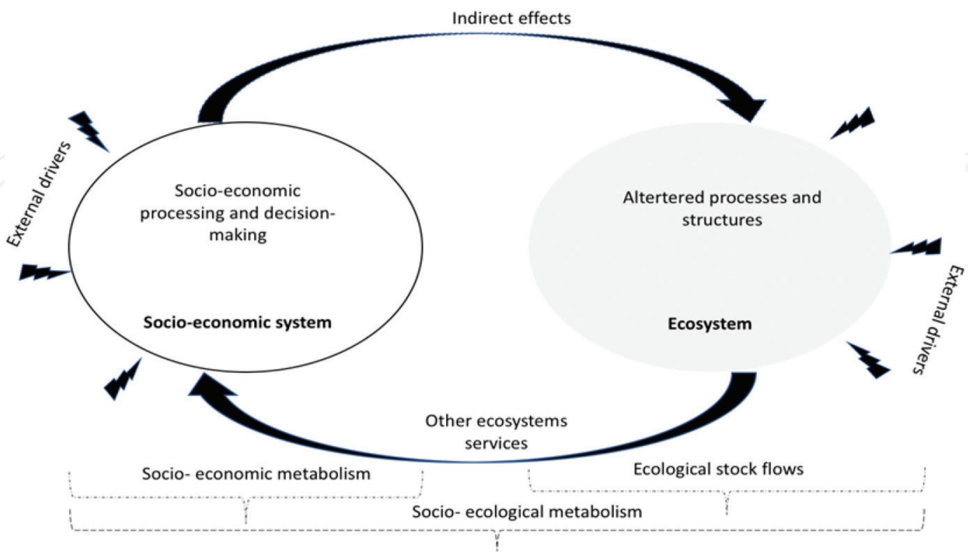

Figure 4. Socioeconomic metabolism conceptualization, adapted from [11].

3. Analysis of the metabolic scaling of cultural, environmental, and economic aspects

From the social metabolism perspective, the evolution of the linguistic families and groups, as a result of social interactions among speakers, help us to understand the dynamics of indigenous communities in Mexico in terms of energy and material flow per period of time. UNESCO has recognized languages as powerful instruments of preserving and developing our tangible and intangible heritage. At the global level, the linguistic diversity is not uniformly distributed. Only nine countries concentrate almost 3500 languages—Papúa, New Guinea, Indonesia, Nigeria, India, Cameron, Australia, Mexico, Zaire, and Brazil [22]. In Mexico, the National Institute of Indigenous Languages has recognized the existence of 68 groups derived from 11 language families with 364 variants in the *Catalog of National Indigenous Languages* [23]. The linguistic families considered are: Álgica, Yuto-nahua, Cochimí-yumana, Seri, Oto-mangue, Maya, Totonaco-tepehua, Tarasca, Mixe-zoque, Chontal de Oaxaca, and Huave. The Mexican federal states that have had the largest number of linguistic groups based on historical settlements are Chiapas and Oaxaca with 14, Campeche with 12, Quintana Roo and Veracruz with 10 (**Figure 5**). Based on the number of speakers, only four linguistic groups concentrate the largest number of speakers: Nahuatl (1,376,000 speakers), Maya (759,000 speakers), Mixteco (400,000 speakers), and Zapoteco (400,000 speakers) [24]. In general, native languages are shaped by human cognitive abilities and process of perception, attention, learning, categorization, schematization, and memory and are used for human socio-cultural interaction. Its origins and capacities are dependent on its role in the sociocultural life of inhabitants of rural communities. As languages plays a fundamental role in society and culture, providing the central means by which cultural knowledge is transmitted over time, the biophysical structures needed for this purpose have been more favored in the cases of Nahuatl, Maya, Mixteco, and Zapoteco communities in terms of the number of speakers than in other cases. Unfortunately, the migration phenomenon has influenced people to go outside from their place of birth searching better economic conditions due to the lack of sustainable development initiatives to be implemented.

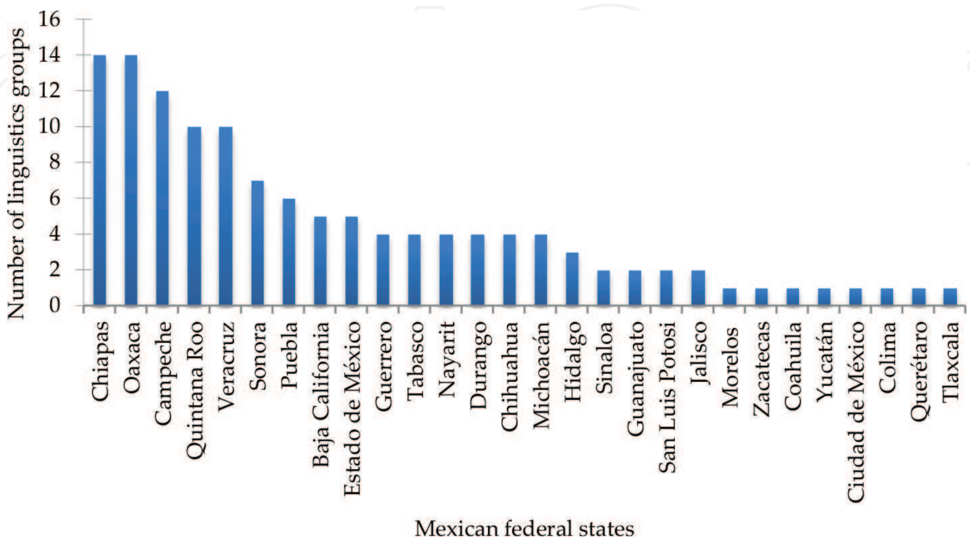

Figure 5. Number of linguistic groups in Mexican federal states.

On the one hand, in 2017, the Mexican Congress approved the General Law of Culture and Cultural Rights (LGCCR) that promotes and protects the exercise of cultural rights and establishes the coordination bases for the access of goods and services provided by the State in cultural matters [25]. Its provisions are of public order and social interest and of general observance in the national territory. The cultural manifestations referred in this law are the past and present material and immaterial elements inherent to history, art, traditions, practices, and knowledge that identify groups, peoples, and communities.

Traditional knowledge of rural communities has played an integral role in their sustainable development, since practices and knowledge have supported the conservation and sustainable use of biodiversity and natural resources [26]. In this way, millions of rural communities throughout the world have used their traditional knowledge to ensure livelihoods and food security in a wide range of ecosystems, taming plants and animals and developing agriculture [27]. Traditional knowledge as a cumulative body of knowledge, know-how, practices, and representations maintained and developed by peoples with extended histories of interaction with the natural environment [28] is part of a cultural complex encompassing the systems of language, nomenclature, and classification, resource use practices, ritual, spirituality, and worldview, which support decision-making at the local level on the aspects of everyday life, such as hunting, fishing, gathering, agriculture, preparation, preservation, and distribution of food, locating, collecting and storing water, dealing with diseases and injury, the interpretation of weather and climate phenomena, clothing and tool manufacture, construction and maintenance of shelters, management of the ecological relationship of society and nature, and adaptation.

Since the 1990s, a number of international agreements, including the Convention on Biological Diversity (1992) and international protocols, such as the Nagoya Protocol (2010), have begun to assess the capacity of traditional knowledge to contribute to progress socioeconomic and environmental protection [18]. With regard to the United Nations General Assembly [29], it recognized in 2007 that respect for traditional knowledge, cultures, and practices contributes to sustainable and equitable development and to the proper management of the environment (61/295—United Nations Declaration on the Rights of Indigenous Peoples). In fact, Article 31 provides that indigenous peoples have the right to maintain, control, protect, and develop their cultural heritage, traditional knowledge, traditional cultural expressions, as well as manifestations of their sciences, technologies, and cultures, including human resources and genetics, seeds, medicines, knowledge of the properties of fauna and flora, oral traditions, literatures, designs, traditional sports and games, and visual and performing arts. Indigenous peoples also have the right to maintain, control, protect, and develop their intellectual property of such cultural heritage, their traditional knowledge, and their traditional cultural expressions. However, in Mexico, the crucial role of traditional knowledge in indigenous rural communities has been ignored over the past few centuries, and they are not passed on to the new generations because they have been devalued and discriminated against since the time of the colonization of the village. There are no initiatives for promotion or dissemination by current governments due to a limited federal budget for these activities, but above all, the right to maintain indigenous intellectual property is continuously violated [30].

As [31] states, Mexico is one of the few countries in the world with mega biodiversity. It has about 10% of all species known in the world (see **Table 1**). Following [31], Mexico has

Country	Vascular plants	Mammals	Birds	Reptiles
Brazil	56,215	648	1712	630
Colombia	48,000	456	1815	520
China	32,200	502	1221	387
Indonesia	29,375	670	1604	511
Mexico	23,424	564	1150	864
Venezuela	21,073	353	1392	293
Ecuador	21,000	271	1559	374
Peru	17,144	441	1781	298
Australia	15,683	376	851	880
Madagascar	9505	165	262	300

Table 1. Mexico biodiversity, adapted from [33].

abundant natural resources: forest, soil, water, and fish resources. Oaxaca is the federal state with the highest biodiversity in Mexico, with 8405 vascular plants, 190 mammals, 736 birds, 245 species reptiles, and 1103 butterfly species [32]. However, during many decades, pressures from economic activities on natural resources have been mounting and most major ecosystems have suffered serious degradation such as biodiversity loss and increased CO_2 emissions.

From the social metabolism perspective, rural communities are not just large collections of people instead they are agglomerations of social links. Space, time, and infrastructure play a fundamental role enabling social interactions in allowing them to become sustainable from the point of view of energy use. In general, social interactions imply cost of people, material, energy, and information flows through networks of infrastructure, but in some cases, the infrastructure does not exist, so citizens do not interact and in consequence, the level of poverty is very high. Here, we show some statistics from Oaxaca [34] (**Figure 6**), Chiapas [35] (**Figure 7**), and Guerrero [36] (**Figure 8**).

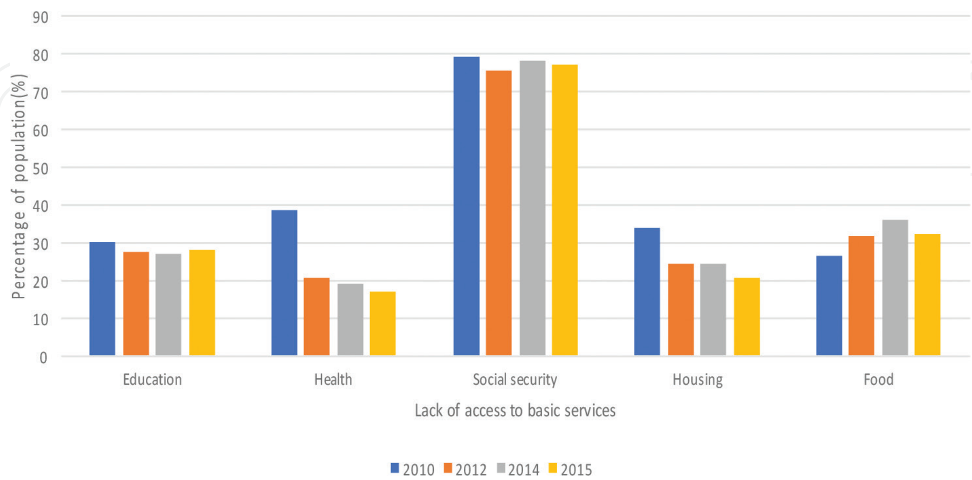

Figure 6. Statistics about the lack of access to basic services in Oaxaca, from 2010 to 2015, adapted from [34].

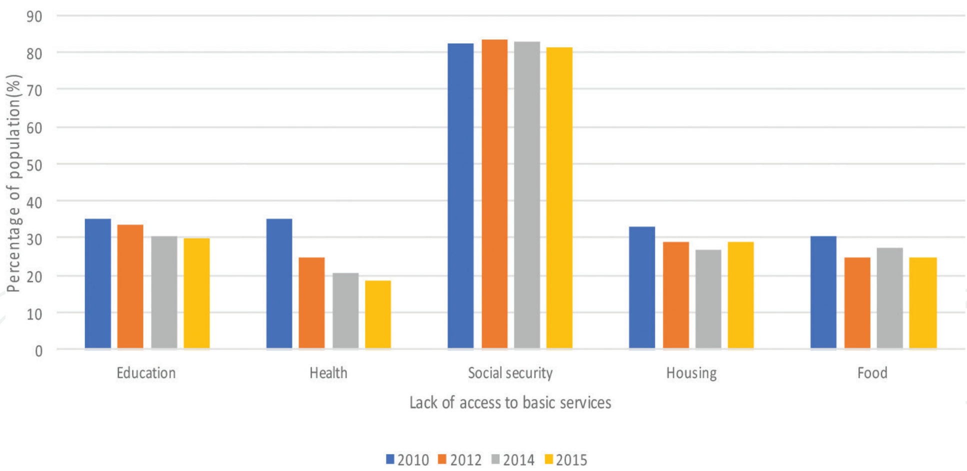

Figure 7. Statistics about the lack of access to basic services in Chiapas, from 2010 to 2015, adapted from [35].

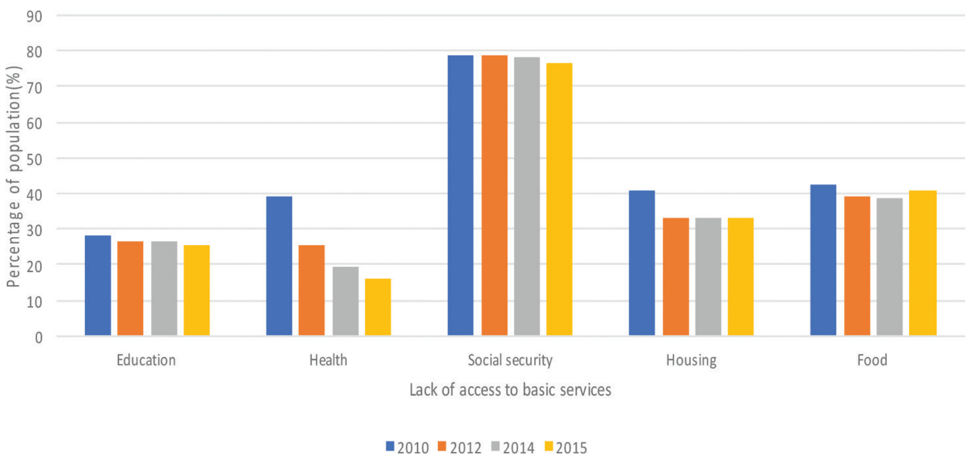

Figure 8. Statistics about the lack of access to basic services in Guerrero, from 2010 to 2015, adapted from [36].

4. Evaluation of the energy necessary to maintain rural communities connected

In this section, we evaluate the energy necessary to maintain rural communities connected. The importance of that is based on the assumption, from the social metabolism approach, that Mexican rural communities to realize their full socioeconomic potential need to expand connectivity per person and of social inclusion because they reproduce in two directions: culturally and biophysically. To quantify the social metabolism of rural communities in terms of energetic and material flows, we need, first, to specify the socio-metabolic regime of Mexican rural communities based on the source of energy used and the main technologies of energy conversion, and second, to calculate the energy flow per capita required that depends on the biophysical structures of Mexican rural communities.

On the one hand, in Mexico, less than three million people live without access to electricity, which are concentrated mainly in rural communities located in southern parts of Mexico [37]. According to the World Bank [38], the level of poverty, the distance from the existing grid, and the small size and dispersion of Mexican rural communities, all preclude efficient grid connection. Following [37], within the next decade, the Mexican government plans to provide electricity to 40–50% of rural communities that lack access to electricity at the moment, where at least 8% of this will come from renewable energy. On the other hand, Mexico's population which lives in the rural areas with access to electricity consumes on an average of 250 kWh per capita per year, while in indigenous communities, geographically embedded in rural areas, the electricity consumption is less than 100 kWh per capita per year. In contrast, population which lives in the urban areas consumes more than 470 kWh per capita per year. Wood and sugarcane bagasse are the basis for thermal biomass applications in the end-user sectors. In rural areas, located in central and southern Mexico, households are the main users of wood fuel for cooking and heating [37].

Nowadays, solar resources in Mexico are barely exploited on any small-scale or commercial basis. However, Northwestern Mexico shows bigger potential for solar power generation where daily average solar irradiation in the region can exceed 8 kWh/m^2 in spring and summer. But the energetic demand is concentrated on the central and the southern zones. The advantage of solar photovoltaic (PV) rural electrification systems is that it can provide electricity to households, agricultural pumping, and mobile phone infrastructure, without access to grid power [37]. In this context, the access to mobile phone infrastructure can contribute to the living

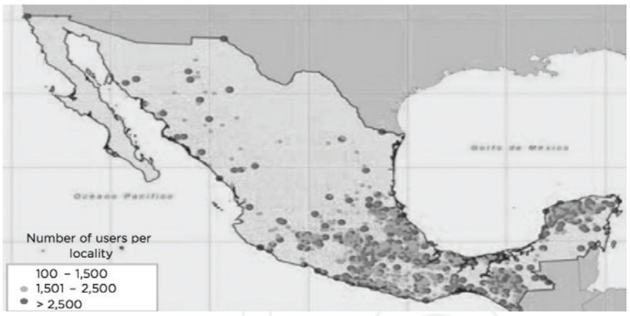

Figure 9. Users of wood fuel per locality, adapted from [36].

Figure 10. Installation of a mini solar PV system for telecommunications purposes, a rural community in Oaxaca Mexico.

conditions improvement of rural communities because it let to expand connectivity per person favoring social interactions that imply cost, material, energy, and information flows through networks of telecommunications that will need to be built gradually (**Figures 9** and **10**).

5. Concluding remarks

The principal purpose of the study is the analysis of the metabolic scaling of cultural, environmental, and economic aspects in the context of Mexican rural communities in order to predict the energy necessary to maintain them connected and estimate their impact on the improvement of socioeconomic development. Social metabolism claims that any social system not only reproduces itself culturally, by communication but also biophysically through a continuous energetic and material exchange with the natural environment and eventually with other social systems. From the ecological perspective, Mexico is one of the few countries in the world with mega biodiversity. It has about 10% of all species known in the world. But, during many decades, pressures from economic activities on natural resources have been mounting and most major ecosystems have suffered serious degradation such as biodiversity loss and increased CO_2 emissions. From the cultural perspective, the National Institute of Indigenous Languages has recognized the existence of 68 groups derived from 11 language families with 364 variants in the *Catalog of National Indigenous Languages*. However, federal states as Oaxaca, Chiapas, and Guerrero present extreme poverty that affects more than half of the population. The rural poverty in Mexico arises mainly from a lack of access to basic services. Also, in Mexico, less than three million people live without access to electricity, which are concentrated mainly in rural communities located in southern parts of Mexico. Poverty, distance from the existing grid, and the small size and dispersion of Mexican rural communities, all preclude efficient grid connection in rural communities where wood and sugarcane bagasse are the basis for thermal biomass applications in the end-user sectors. Unfortunately, solar resources in Mexico are barely exploited on any large-scale or commercial basis mainly due to the distance between supply and demand which means that planning is needed for transmission infrastructure in coordination with solutions for grid integration of renewables. It is important to note that infrastructure plays a fundamental role in enabling social interactions in allowing them to become open-ended in terms of increased connectivity and sustainable from the point of view of energy use. Finally, as the land use intensification denotes increase in socioeconomic inputs and/or outputs from land and thus closely refers to socioeconomic material or energy flows; we consider that it needs to be based on traditional knowledge of communities locally as it implicitly endorses practices of conservation and sustainable use of biodiversity and natural resources.

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Author details

Aida Huerta Barrientos[1,2]*, Alma Elia Vera Morales[1] and Tania Vázquez González[1]

*Address all correspondence to: aida.huerta@comunidad.unam.mx

1 Department of Operations Research, Faculty of Engineering, National Autonomous University of Mexico, Mexico City, Mexico

2 The Complexity Sciences Center, National Autonomous University of Mexico, Mexico City, Mexico

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