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Scenarios of Sustainable Development for Geothermal Projects

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ABSTRACT

As occurs for any type of energy technologies, the development and utilization of geothermal energy bears the possibility of causing undesired impacts on the environment, society and economy (ESE). Hence, it may be worth to assume if the amount of energy is to be maximized and the impacts minimized, thus generating benefits according to the principles of sustainable development. At the (testing) site and technology level, the degree of impact on ESE will depend mainly on the natural characteristics of the reservoir, the social complexity of the human communities and the applied technology of the project. Therefore, it is critical to integrate the three ESE aspects of sustainable development during every stage of the planning of any geothermal project (exploration, production tests, construction and operation). In this work, we present the first approximation of the monitoring, update and prospection of the aspects of ESE. As well as, developing plans of sustainable development and territorial planning in Mexico at Acoculco, Puebla, an exploration site (greenfield); and Los Humeros, Puebla, a geothermal power plant operating more than 25 years (brownfield). The first results show that the environment is equally affected in both areas, even in Los Humeros the forested area is increasing within the time in comparison with Acoculco, were is the opposite. In both sites, society is similar, but in Los Humeros, are settlements of indigenous groups. Economic development is marginal in both areas and poverty indexes are high.

1. INTRODUCTION

In recent years, the issue of energy production has been on the national and international debate. The discussion has been focused on the generation of agreements and actions for the care of the environment, due to the impacts generated by humans. These impacts have been reflected in the pollution of water bodies, acidification of soils (IPPC, 2001), the emission of greenhouse gases (GHG), air pollution and the ravages that these alterations have generated in human health. Mexico is currently in an energy transition, which requires investment on renewable energy such as geothermal energy, which makes use of high subsoil temperatures to obtain electricity or heat for various processes.

Geothermal power plants are extremely reliable and usually work more than 95% of the time. This compares to availability of 60% to 70% of the nuclear and coal-based power plants (Kutscher, 2000; Cardell, 2007; Zeyringer, 2017). Geothermal energy is recognized as an important and practically renewable energy source, inexhaustible, with a solid technological maturity, clean, versatile and useful for generating electricity, among other multiple applications (Shortall, 2015; Kononov, 2002). The use of the geothermal resources has demonstrated technical and economic viability to produce energy with a sustainable awareness, determining that the energy extracted from the geothermal reservoir can be recovered in a time scale similar to the one used in its extraction (Rybach and Monguillo, 2006).

Talking about technology development, the concept of a greenfield is an area normally undeveloped, while a brownfield is related to a site where a previous development has been done. A greenfield is expected to be a clean site with little to no contamination and a brownfield normally is catalogued as a disturbed area according to the activity of the applied technology. For almost 20 years, brownfield redevelopment and greenfield protection have been land use strategies that accentuate long-term sustainability goals rather than unrestricted economic growth and resource depletion (Dorsey, 2003). In this work, we consider these terms to define and compare a geothermal exploration zone as a greenfield and a geothermal power plant with almost 29 years in operation as a brownfield. Both sites located in a similar territory socially and economically speaking, with geothermal and environmental particularities.

This document identifies and analyzes the main problems and common aspects that influence goods and services, trying to diagnose them and integrate them into a single proposal, to constitute in itself an instrument for planning, designing intervention strategies and coordinated policies that allow progress towards an Ecosystem Approach Management (EAM). The main premise of this work is "to move towards sustainable management by first achieving a balance between social needs, economic interests, and environmental importance, i.e., management capable of maintaining integrity, biological diversity, and ecosystem services for present and future generations despite changing climatic and social pressures.

1.1 Site Description

Both sites are located in the state of Puebla, east from Mexico City (Figure 1). The zone of Acoculco is located in the limits of the states of Puebla and Hidalgo, in the municipality of Chignahuapan, Pue, 85 km NW of the city of Puebla and 65 km SE of the city of Pachuca Hidalgo. It is between the coordinates 19°47" and 20°02" N latitude and 97°55" and 98°20" W longitude. Its elevation is between 2,800 and 2,900 mosl. From the physiographic point of view, it is located in the eastern portion of the Mexican Volcanic Belt, very close to the limits with the Sierra Madre Oriental. In the other hand, Los Humeros geothermal power plant is located in the central-eastern part of Mexico approximately 25 km NW of the city of Perote, within a complex caldera type volcanic center less than 500,000 years old (Yañez and García., 1982; Ferriz and Mahood, 1984). This volcanic center is located in the eastern part of the

Mexican Neovolcanic Volcanic Belt of the Plio-Quaternary (Robin, 1982), almost on the border with the alkaline volcanic province of the Gulf of Mexico.

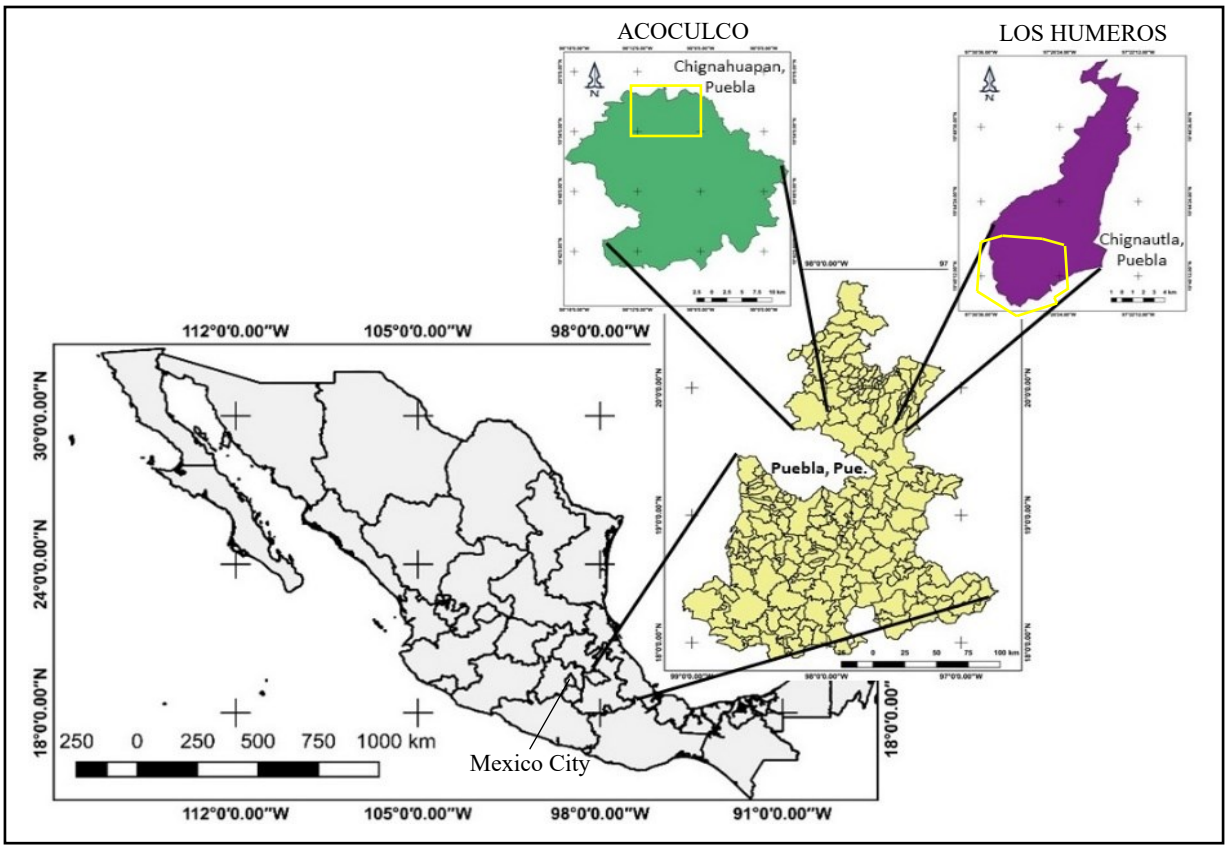

Figure 1: Sites of study: Acoculco and Los Humeros, Puebla, Mexico.

1.1.1. GREENFIELD

The geothermal zone in exploration of Acoculco, Puebla, is located 85 km NE of Puebla City and 180 km from Mexico City. At the beginning of the 80s, the Federal Electricity Commission (CFE) has considered Acoculco a zone of geothermal interest as a potential site to develop a geothermal power plant. Although, surface manifestations of geothermal activity are scarce and consist of low temperature, bubbling acid-sulfate springs that are mainly concentrated in two areas (Los Azufres and Alcaparrosa) with a separation of around 1.8 km each other. Despite this, the geothermal interest of the area has been based, on the existence of the emanation of gases of magmatic origin. Gases such as: CO_2, H_2S, H_2, He, N_2, Ar and Ne, as well as the high isotopic concentration of He in the springs of Los Azufres (3He/4He = 8.5) considered one of the highest in the Mexican Volcanic Belt, which has suggested a high geothermal potential worth to explore (Rocha-López et al. 2006).

The Acoculco Caldera is circa 18 km wide and formed as a response of two main periods of volcanic activity (López-Hernández et al., 2009). Two exploratory wells have been drilled in the area. In 1995, well EAC1 was drill to a depth of 1,810 m, in the area of Los Azufres, whose results were unexpected because although the temperature was very attractive (260 °C at 1,500 m depth) the permeability was almost cero. In 2008 well EAC2 was drilled to a depth of 1,900 m, located at 500 m NE from EAC1 as a pararell experiment to EAC1. With the compilation and integration of field data and the elaboration of stereograms, the presence of four structural systems were established within the thermal zones of Los Azufres and Alcaparrosa, structures that create the favorable conditions of permeability, that undoubtedly control the flow of thermal fluids at depth (Rocha-López et al., 2006).

1.1.2 BROWN FIELD

Los Humeros volcanic system is associated with an important silicic volcanic center and is located around the latitude of 19°40´N and the longitude of 97°25´W, about 180 km east of Mexico City, on the northeastern end of the Mexican Volcanic Belt, at an elevation of 3000 mosl. Los Humeros is an 18 to 20 km wide circular caldera structure, with an inner younger caldera 5-8 km wide (Los Potreros).

The firs deep well was drilled in 1982, and the commercial exploitation of the geothermal resource by the CFE began with the installation of the first 5 MWe unit in 1990. From 1990 to 2012, more than 40 wells were drilled and 7 units of 5 MWe were installed (Quijano and Torres, 1995). Currently, more than 50 wells have been drilled; 25 production wells, mainly located in the Los Potreros caldera domain, produce circa of 6 Mton/year of steam to fulfil a installed capacity of 94 MWe (Romo-Jones et al., 2018). The main production wells are located in the northern part of the field.

In general, most of the wells produce high enthalpy, two-phase discharges, while a few wells such as the H-1 and H1D produced a relatively high fraction of water at separator conditions. The relatively low salinity water produced by wells is classified mainly as bicarbonate or sulfate type rather than chloride type.

2. MONITORING OF ESE ASPECTS

2.1 Environment

This aspect is evaluated according to the description of the sites, focused on climate, hydrology, soil types and biodiversity. To establish the actual state of the site is necessary to make an evaluation of water, soil and air quality, an estimation of plant and animal species, identification of bio-indicators and environmental indicators, etc. However, in this work only the environmental units are presented as the actual state of the site.

To describe the effects that may alter the environment, an analysis of the processes of change in vegetation cover and land use was made, comparing two maps of cover and land use for the same area. The comparison carried out in this study was with digital maps from 1993 and 2017. The information to develop the maps was obtained through the CONABIO information geoportal referring to the National Institute of Statistics, Geography and Informatics (INEGI), in the digital database called "Series I and Series VI". Using equation 1 proposed by FAO (1996).

$$\delta_n = \left[\left(\frac{S_2}{S_1}\right)^{1/n} - 1\right] * 100 \quad (1)$$

Where δ is the change rate in percentage, S_1 is the surface in the date 1, S_2 is the surface in the date 2 and n is the number of years between both dates

2.2 Social

This aspect is presented with a brief description of the localities within the influence area, including some customs and traditions. The territorial dynamics is presented with a summary of the land usage, identifying social routes according to their socio-cultural behavior.

2.3 Economic

In this aspect, a socioeconomic status and a summary of the core services in the communities are presented, in order to establish the actual state of the sites.

2.3 Sustainable Development

Finally, the sustainable development is addressed identifying common aspects and main problems in both sites to propose a balance between social needs, economic interests and environmental importance. This information is a main start point to establish Scenarios of sustainable development of geothermal projects.

3. RESULTS ENVIRONMENT

3.1 Greenfield

3.1.1 Climate

Acoculco has a temperate sub-humid climate, with rains in summer and autumn. The rainy season in this area is from May to October. Maximum total rainfall is recorded in July and October, with 423 and 303 mm, respectively. However, the historical average indicates July and September as the rainiest months, with 117 and 111 mm in monthly average, respectively. The average temperature ranges from 8 to 14 °C all year round. With minimums of -1 °C in winter and maximums of 22 °C in summer.

3.1.2 Hydrology

The exploration polygon in Acoculco is in a watershed of two hydrological sub-basins, which are part of two distinct hydrological regions. The sub-basin in the NW part is known as the Metztitlán River (RH26Dv), which is part of the Pánuco Hydrological Region and the Moctezuma River Basin. It is a closed type with an area of 2,821.42 km^2. The direction of runoff from the study area is to the NW. The Laxaxalpan sub-basin (RH27Bc) is the other sub-basin of the site, with a surface area of 1,608.95 km^2. It is an open type watershed. It is part of the Tuxpan-Nautla hydrological region and the Tecolutla River basin. From the study area, there is a NE runoff direction. Within the zone there are no permanent effluents, rather they are temporary and depend on precipitation (Rosas, 2017).

3.1.3 Soil

The Acoculco study area comprises an area of approximately 148.5 km^2, in which seven soil units are described (INEGI, 2014), where six main soil groups are defined (IUSS Working Group WRB, 2015), presenting different proportions and specific physical and biochemical properties (FAO, 2009) depending on the unit. In general, the zone is composed of soils that present surface horizons rich in organic matter of fine and medium surface textures, which may present clay accumulation in underlying horizons, and shallow in some areas. The predominant soil is the Andosol, followed by Phaeozem, followed by Regosol, and with a minor proportion of Durisol and Vertisol.

3.1.4 Biodiversity

Forest: Forest is defined as a mass of arboreal vegetation; in the zone of study the following types of forest are present:
Pine forest: It occupies 40.5% of the study area, approximately 49,900 hectares, the main species found are Pinus patula, P. moctezumae, P. ayacahuite var. veitchli, P. leiophyla, P. pseudostrobus, P. rudis, and P. teocote, d within the shrub stratum are species such as Arbutus xalapensis and Baccharis conferta.
Pine-oak forest: It is found in 2.3% of the total surface, equivalent to 2987 hectares. Consisting mainly of species of the genera Pinus and Quercus, they are generally low forests, with thin, slow-growing trunks100; the oak species that can be found are Quercus crassifolia, Q. scytophylla and Q. conglomerata; species such as Alnus jorullensis, Arbutus xalapensis, Baccharis conferta and Pteridium sp. are also present.

Induced grassland: A plant community dominated by grasses (grasses or grasses), originated by human influence, in abandoned agricultural areas or by the removal of original vegetation. It is important to mention that in the municipality of Chignahuapan is also present the forest of Oyamel with (0.64%) is located in the highest parts of the municipality between 2,500 and 3,200 meters above sea level, the dominant species is Abies religiosa, commonly mixed with species of the genus Pinus and sometimes with Quercus.
In the Acoculco exploring site, 17 herpetic-fauna species have been recorded (5 amphibians and 12 reptiles). In average, with a relative abundance of 0.13 and a Shannon number of 1.53. The birds registered in this zone correspond to mainly resident birds with some migratory species with a relative abundance of 65 and a Shannon number of 3.4. In the case of non-flyer small mammals, the relative abundance was 5 with a Shannon number of 1.42.

3.1.5 Environmental Units

Understanding demographic processes in rural areas is of particular importance for environmental analysis. In the case of Chignahuapan Pue, there is an environmental regional system (ERS) of predominantly agricultural and forest landscape.

The EU are described by combining environmental indicators as homogeneous territorial units with diagnostic elements such as physiography, vegetation, land use and landscape, especially the natural environment. These descriptors sometimes do not have a clear definition between the different patches of different classes, so the transition between classes is not very clear. Zoning into environmental units for the study area represents the diagnosis of the degree of alteration of the plant community and allows understanding the dynamics of fragmentation through changes in land use within the landscapes. In Figure 2, the environmental units of Acoculco exploring site are presented, where annual temporary agriculture is the main EU in the site, followed by pine forest and secondary pine forest vegetation.

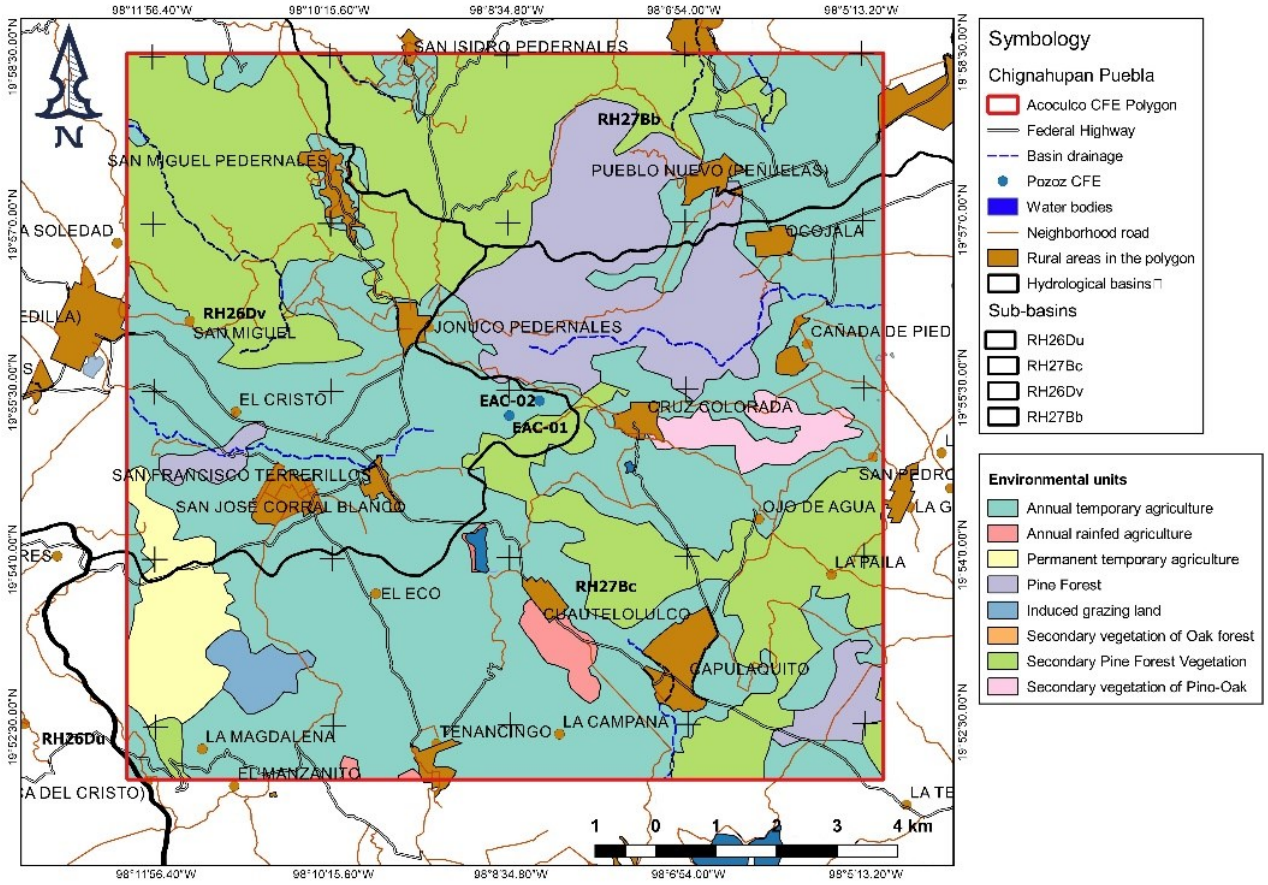

Figure 2: Environmental Units verified in field in year 2018, Acoculco, Puebla, Mexico.

3.1.6. Cover and land use rate

Comparing the land use and plant coverage maps from the site in year 1993 (Figure 3) and year 2017 (Figure 4).

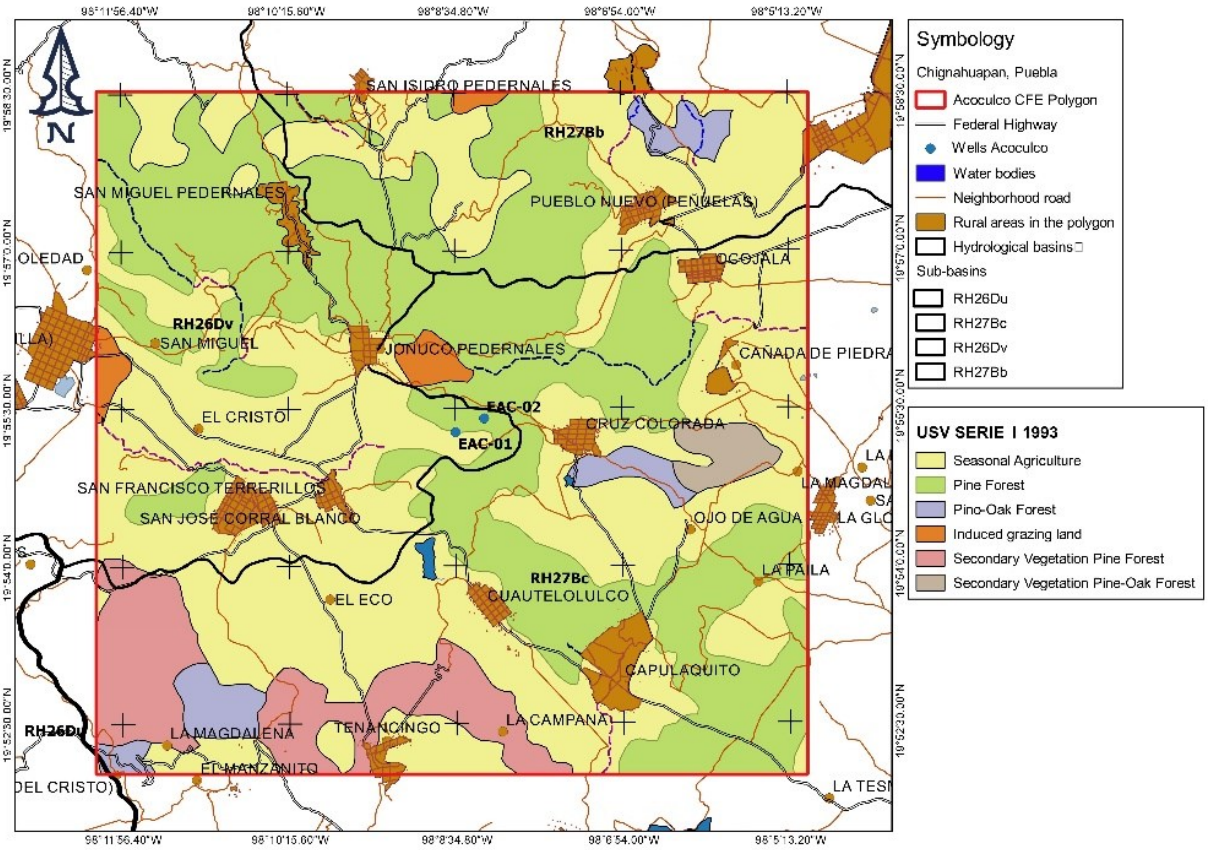

Figure 3: Land Use and Plant Coverage of Acoculco, Puebla, Mexico (1993).

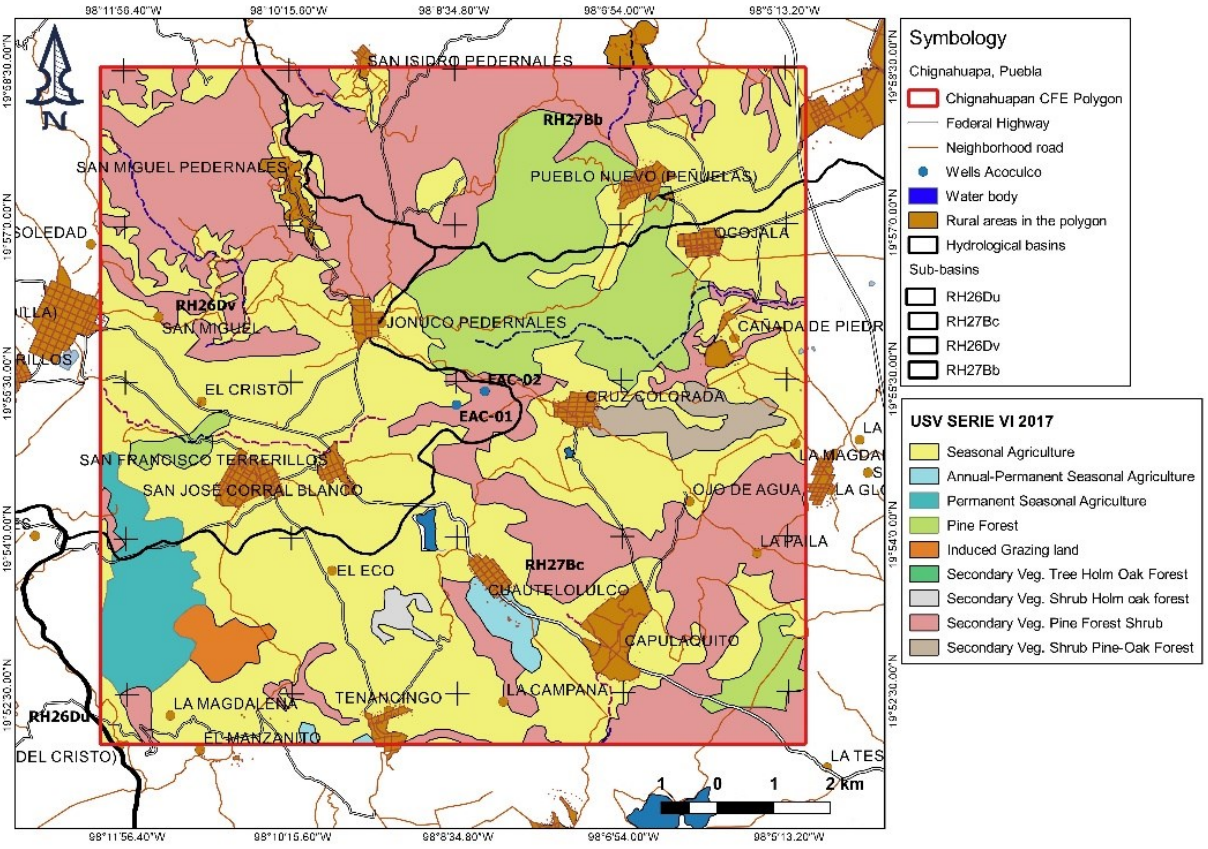

Figure 4: Land Use and Plant Coverage of Acoculco, Puebla, Mexico (2017).

From the maps, can be appreciated that in 24 years the pine forest has been changed by secondary vegetation of Pine Forest Shrub, some seasonal agriculture sites appeared mainly in the South part. A permanent seasonal agriculture zone appeared in the SW part. In a south area close to Cuautelolulco an area of annual permanent seasonal agriculture is identified as a land change for the development of socioeconomically activities in the zone. If we compare these two maps, (Figures 3 and 4) made with national public information published by INEGI, with the map developed by our research group in year 2018. There are, no significant changes in the EUs, except the fact of the the recovery of pine forest in the center of the zone, close to the geothermal exploration wells. Due to reforestation activities by inhabitants of Cruz Colorada community, advised and financed by the forest national commission though the payment of environmental services.

According to the calculation of equation 1, the loss of vegetation coverage of the pine forest was 35.32%.

3.2 Brownfield

3.2.1 Climate

According to the climatic classification of Köppen, modified by García (1998), the type of climate corresponding to the location of Los Humeros corresponds to a type of semi-dry or semi-arid climate (the P/T ratio is greater than 22.9). Temperate with warm summer (average annual temperature ranges between 12° and 18 °C). With summer rainfall regime (the percentage of winter rainfall with respect to total annual rainfall ranges between 5 and 10.2 mm), isothermal (ranges 4.7 °C), has Ganges type temperature with a relative decrease in rainfall in the months of July and August during the rainy season.

3.2.2 Water

The municipality of Chignautla is located within two hydrological regions. The southern part includes the intermittent currents that drain into the sub-basin of Lake Totolcingo (RH18Ah-L) in the San Juan plains, within the Atoyac basin that is part of the Balsas region. The northern part of the municipality forms part of the Tecolutla river basin, and comprises two sub-basins. To the west are the tributaries of Apulco (RH27Be-R.), and to the northeast the sub-basin of the river Joloapan (RH27Bf-R). Some of the most important rivers in Chignautla are the Caja de Agua and the Ateta, tributaries of the Joloapan; and the Viga Ancha, which is a tributary to Apulco.

3.2.3 Soil

The Humeros study zone comprises an area of approximately 150 km^2, in which seven soil units are described (INEGI, 2014) where four main soil groups are determined (IUSS Working Group WRB, 2015), which present different proportions and specific physical and biochemical properties (FAO, 2009) depending on the unit. In general, the study area is composed of soils that present surface horizons rich in organic matter, with medium and coarse surface textures, shallow soils, and soils with low pedogenetic development. According to the classification of soils elaborated by the FAO-UNESCO (1991), the predominant soil is the Andosol, followed by Regosol, and with a minor proportion of Leptosol.

3.2.4 Biodiversity

The municipality presents generally reduced and isolated wooded zones, to the south and extreme north, they are constituted by forests of pines, where the following species predominate ocote, escobilla, jarilla, zacatón, liendrilla, pine, oyamel and madroño. There are also large areas of induced grasslands in the center and south, which have grown at the expense of the forests, threatening to destroy them. Fauna variety present in the site are reptiles such as rattlesnake, and spikeleton, rabbit, hare, coyote, skunk, sparrowhawk, owls, and variety of songbirds such as springs, chahuices, sparrows, etc. In Los Humeros geothermal power plant, 14 herpetic-fauna species have been recorded (4 amphibians and 10 reptiles). In average, with a relative abundance of 0.092 and a Shannon number of 1.12. The birds registered in this zone as in Acoculco, correspond to mainly resident birds with some migratory species with a relative abundance of 28 and a Shannon number of 2.4. In the case of non-flyer small mammals, the relative abundance was 6 with a Shannon number of 1.25.

3.2.5. Environmental Units

In Figure 5, the environmental units of Los Humeros geothermal power plant is shown, here it can be observed that the main units is induced grassland followed by pine forest and secondary vegetation of pine forest, with some places mainly close to the communities where annual rain fed agriculture is practiced.

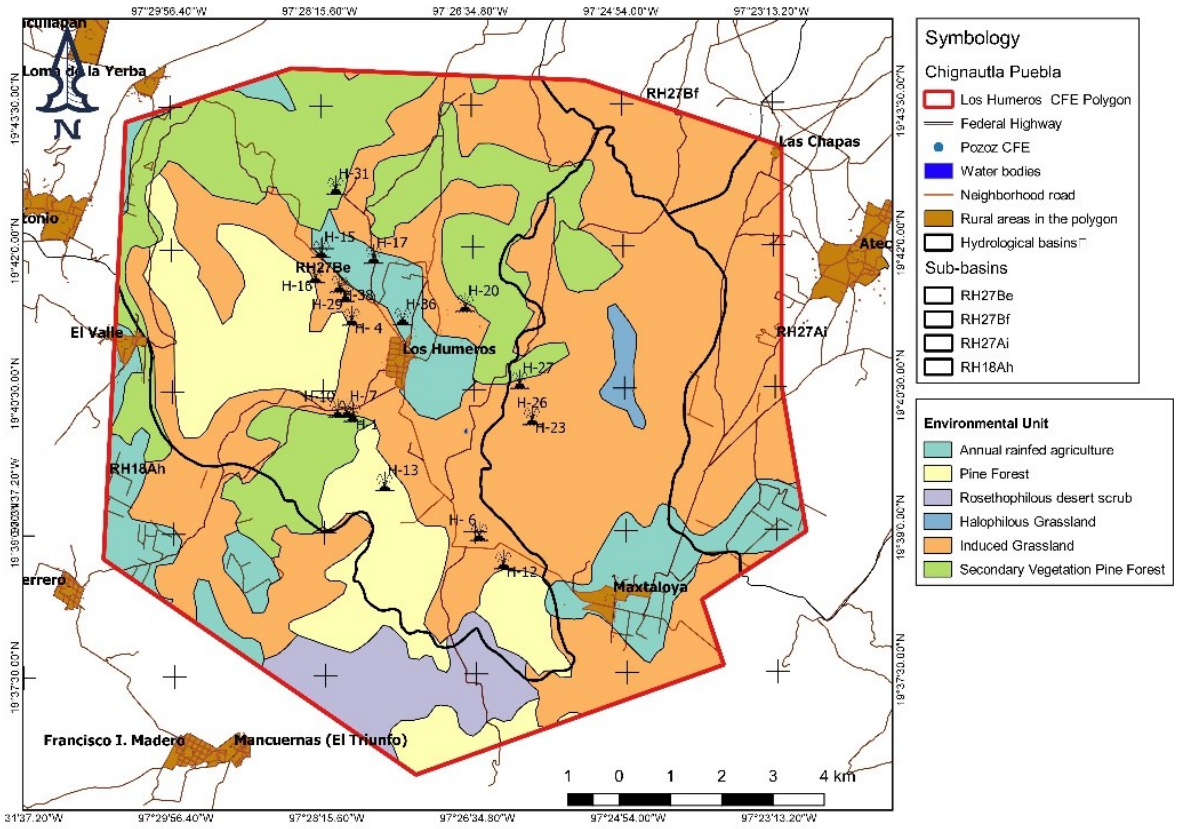

Figure 5: Environmental Units verified in field in year 2018, Los Humeros geothermal power plant, Puebla, Mexico.

3.1.6. Cover and land use rate

Comparing the land use and plant coverage maps from the site in year 1993 (Figure 6) and year 2017 (Figure 7).

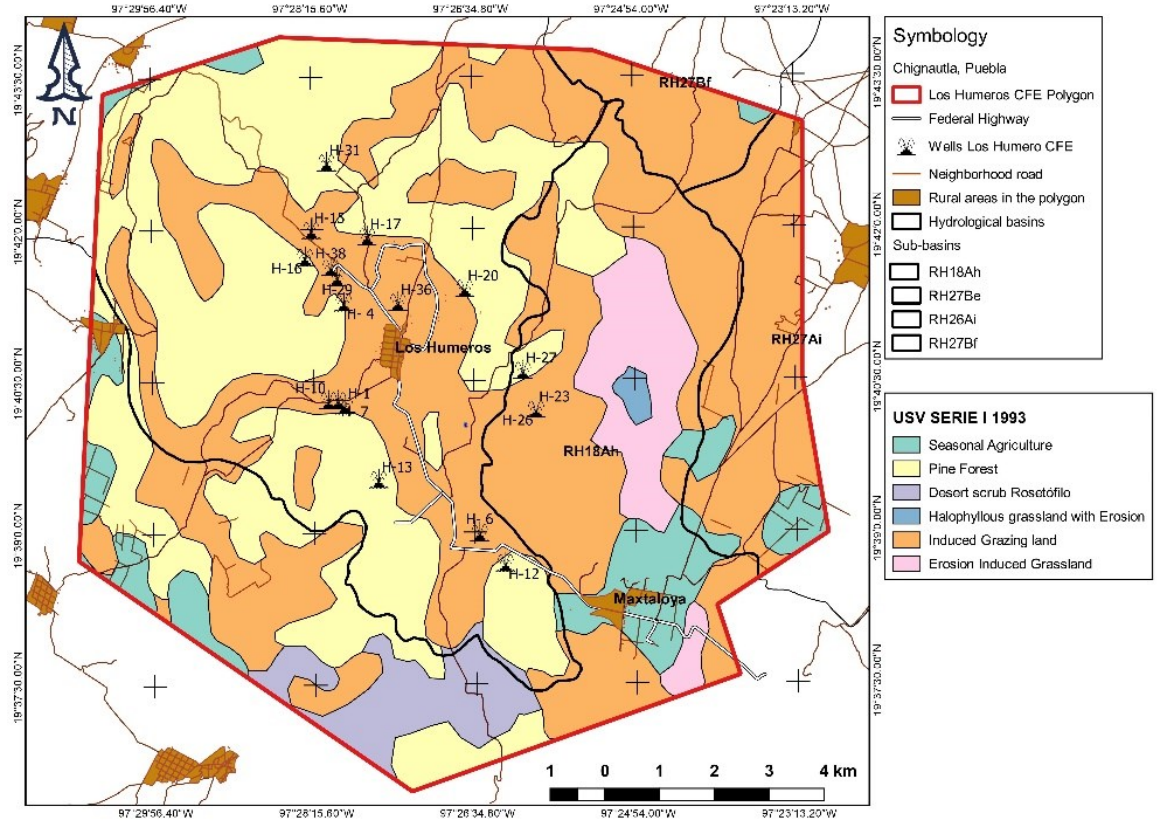

Figure 6: Land Use and Plant Coverage of Los Humeros geothermal power plant, Puebla, Mexico (1993).

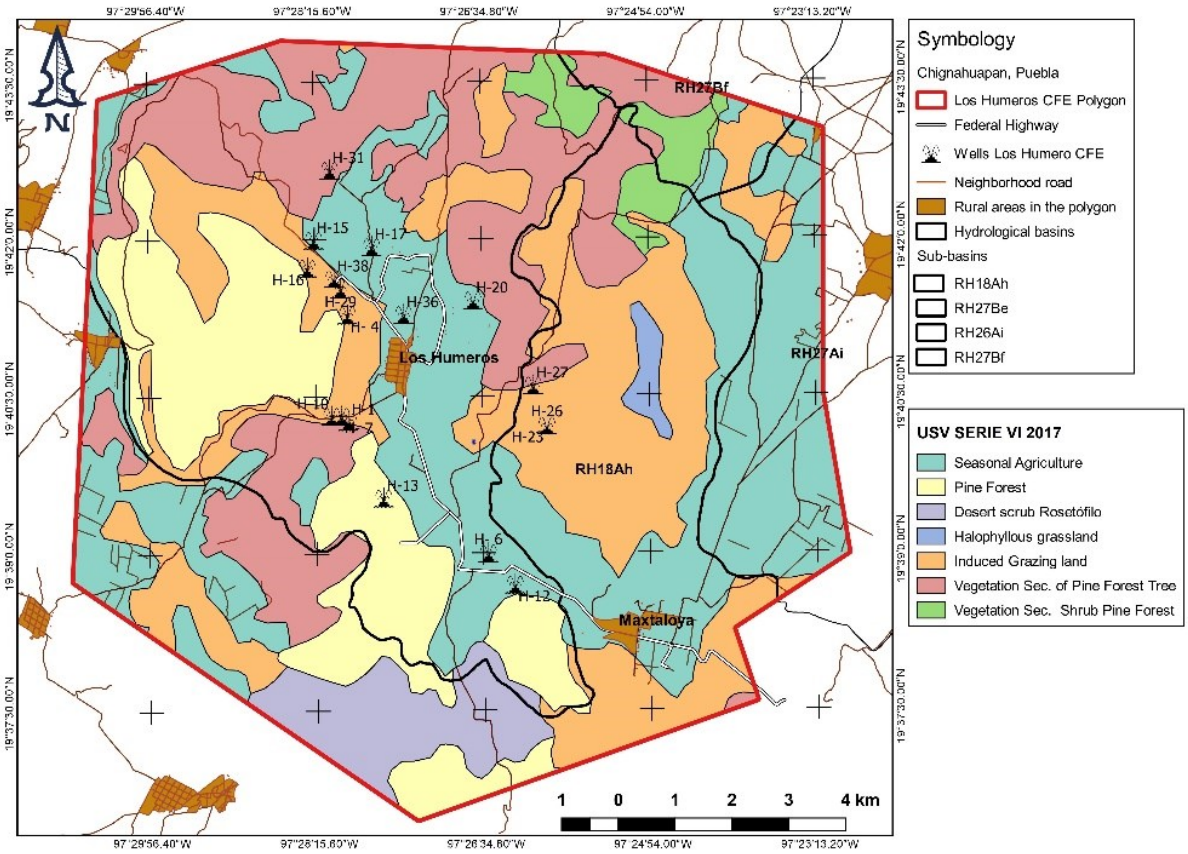

Figure 7: Land Use and Plant Coverage of Los Humeros geothermal power plant, Puebla, Mexico (2017).

From the maps, can be observed that in 24 years the pine forest has been changed by secondary vegetation of Pine Forest and seasonal agriculture in the NW part. It is important to highlight the increment of seasonal agriculture area in the central and east part of the zone. In year 1993 there were two zones, one with desert scrub and another with halophylous grasslands that are representative of the zone and in both cases, in year 2017, the area was increased but not significantly. Other remarkable change has been the changes between erosion-induced grassland (1993) to induced grassland (2017, 2018). Due to the reforestation activities by CFE, to prevent erosion and promote the development of fertile soil.

If we compare these two maps, (Figures 3 and 4) made with national public information published by INEGI, with the map developed by our research group in year 2018. There are significant changes in the EUs, especially in the seasonal agriculture unit that changed back in 2018 to an induced grassland. This change can be attributed to the efforts made by CFE and its campaigns of reforestation in the zone and that the climate change has affected the rainy seasons making agricultural activities unsustainable for the communities.

According to the calculation of equation 1, the loss of vegetation coverage of the pine forest was 44.71%. This percentage is bigger than the calculated for the greenfield, however, the main activity that changed the land cover was the agriculture which is not a proper activity from the geothermal power plant. Even in year 2019 the efforts in reforestation has changed the agricultural fields to an induced grassland and even the areas affected by soil erosion in year 1993 have been recovered by CFE, which is a positive environmental impact in the zone.

4. RESULTS SOCIAL

4.1 Greenfield

The communities are located not only in towns defined according to the criteria established by INEGI, but also in dispersed settlements of very few inhabitants with lack of public services, some of them within the study area and others in the zone of influence. The zone of influence was defined by their proximity within the geothermal resource; in this case, the communities of Cruz Colorada, San Francisco Terrerillos and Jonuco Pedernales were taken into the core zone. All of them belong to the municipalty of Chignahuapan.

These communities are organized in an ejidal system, like the entire Mexican rural territory. Each ejidal nucleus is divided into agricultural, communal, school and forest plots distributed among ejidatarios. The living area is divided into plots. Each ejido is administered by an ejidal commissariat, a treasurer, an assistant president, a secretary, a justice of the peace and a supervisory council.

According to the catalogue of indigenous communities in 2010, indigenous people in the zone of geothermal influence are located in San José Corral Blanco (two people) and in Cruz Colorada (three people), finding not an indigenous community in the zone (CDI, 2010).

4.1.1 Customs and traditions

The populations are calm; it is daily to see shepherds with flocks of sheep, equestrians on horseback, and women with rebozo walking with children along the roads. As they are peasant populations, the men who work the plots leave early to carry out their tasks, eat in the field, return in the afternoon to rest, and continue their work in the plot. Maize, barley, beans and peas are planted for domestic consumption. Some with larger plots sell the crop. There is a strong movement of people towards the cities of Puebla and Mexico, because during the week they live and work in the city to return to work on the plots on weekends. More and more women are also going to live in the cities; they work cleaning houses or in shops, and the men generally work in masonry. There is also migration to cities in the United States. Sometimes those who migrate no longer return to the communities, so it is common to see young children and even teenagers in the care of grandmothers. Most of the inhabitants use wood from the forest have chickens, turkeys, pigs and some have sheep, mules and horses.

These are mestizo populations, with a rich culinary tradition typical of the center of the country, consisting of corn, beans and chili. Some inhabitants produce pulque, a drink derived from the maguey that abounds and gives its characteristic stamp to the landscapes of this region.

4.1.2 Land Uses

The predominant land use is rain fed agriculture, distributed throughout most of the municipal territory, except in mountainous areas where the vegetation is coniferous, generally associated with secondary shrub vegetation. Among those that predominate in the area is the pine forest, which is distributed in a strip in a south-southeast direction, a small portion of pine forest is located to the west of the entity. Induced grassland is present in one unit to the west and a smaller unit to the northwest. Another land use is urban, which occupies an area of 3,523 hectares (2.8%) of the total area, inhabited by populations of more than 2,500 people, referring to the physical space built with various buildings and public service infrastructure, located mainly in the western portion.

Agriculture: Different types of crops are produced, such as rain fed or irrigated. In the study area, rain fed agriculture occupies 65,405 ha, equivalent to 52.3% of the surface area within the territory.

The alterations carried out on the natural vegetation, by the constant demand of space for agriculture of temporary occupying 59.9% of the municipality, the cattle sector represents 2.5% and is associated to the agricultural activity. Both activities are developed in unsuitable areas, causing the loss of original vegetation and disturbing the natural dynamics, so it is a factor to consider in the analysis of the dangers of the municipality. Anthropogenic activities are considered the main causes of increased levels of desertification, deforestation, habitat fragmentation and loss of biodiversity. For this reason, "it is extremely important to identify the areas where the intervention of society is a priority to carry out restoration activities in order to reverse the degradation process present in the area, therefore, it is necessary complementary strategies that promote restoration, conservation and use in a rational manner. This is of great relevance because in the regions with pine-oak forests it is home to a fragile biodiversity, an area where the most significant losses of native forest cover are observed.

4.2 Brownfield

The annual report on the situation of poverty and social backwardness of 2010 describes Los Humeros as a locality with less than 2500 inhabitants, where 149 of them are people with an age of 15 years and more who did not finish their basic education; it highlights that 67% of the population are under 29 years.

According to the catalogue of indigenous communities in 2010, indigenous people in the geothermal power plant of Los Humeros in Chignautla from 801 inhabitants, 111 are of indigenous origin, while in Los Humeros from 416 inhabitants, 199 are from indigenous origin. The indigenous population of the zone are from the groups: Chocho, Mixteca and Náhuatl (CDI, 2010).

4.2.1 Customs and traditions

Agricultural activities are seasonal, where the following are sown: beans (Vicia faba), barley (Hordeum vulgare), oats (Avena sativa), maize (Zea mays), beza (Vicia sativa) and in some cases canola (Brassica napus); crops are located around urban areas and along environmental units.

4.2.2 Land Uses

In portions of open forests on the southern slopes of the Zotoltepec hill there are some small areas with problems of laminar erosion and gullies caused by the effects of rains and complemented by the wind, due to the fragility of the soil generally sandy and with a maximum slope of 55% and minimum of 15%; therefore, restoration activities are urgently needed.

Forests are exploited for construction, quarries, pink sand, concrete, limestone and malpais stone are other natural resources exploited in the zone.

5. RESULTS ECONOMIC

5.1 Greenfield

5.1.1 Socioeconomic status

Acoculco had 1,735 inhabitants (891 men and 844 women) until 2010. The municipality has a high degree of marginalization, with 20% illiteracy among the population aged 15 and over. Until 2010, 24.27% of the population did not have access to health services, a situation that has improved with the Popular Insurance established in the region in recent years.

The municipality of Chignahuapan presents a considerable degree of marginalization due to the fact that 62.9% of the communities are classified with high marginalization, 7.5% with very high marginalization, 10% of the communities are classified with medium marginalization and only 19% of the communities have a low or very low degree of marginalization (CONAPO, 2010). This may be

mainly due to the fact that most communities are far from the municipal capital and do not have the basic services to meet their essential needs.

Several studies have modeled and analyzed the deforestation process considering socioeconomic and environmental variables. This process may or may not be repeated in other localities of the studied region. Therefore, it is important to know the environmental, social and economic patterns that stimulate deforestation and its threats by activities incompatible with the maintenance of environmental quality. This aspects will permit the identification of biologically significant areas, starting with a large-scale inventory of patterns of landscape, vegetation and habitat structure, as well as the natural vocation of the soil at different spatial scales for the generation of future scenarios of land use.

The change from forest use to seasonal agricultural use observed in the field has a significant relationship with the degree of marginalization of the different populations of the communities located within the polygon determined by the CFE as an exploration zone. When reviewing in detail the definition of the units denominated as Urban Zone is necessary to make a new classification to denominate them as Villages and to make a diagnosis to the different communities depending on the population and basic services.

For this adjustment, 14 localities with less than 50 inhabitants that do not have information in the census and do not have basic services of water, drainage and electrical energy (field observation) were considered, which will be called Rancherías. Four localities that according to the census (INEGI, 2010) have between 50 and 100 inhabitants that do not have basic services, called for this classification as small towns. Twelve localities with a population of between 100 and 500 inhabitants recognized as middle-sized towns, where more than 50% of their homes do not have basic services, and finally, those localities with more than 500 inhabitants where more than 50% of their homes have electricity, water and drainage services were recognized as towns.

This classification is very important as information for the environmental diagnosis due to the fact that in the localities where there are no water and drainage services, septic tanks are surely used and water is supplied in wells with doubtful water quality, which may be having repercussions on environmental and public health conditions.

5.1.2 Core Services

Most homes have no drainage, septic tanks and single pit latrines are used. There are still houses with dirt floors (as of 2010 it was reported that 9% of the houses had dirt floors) and 2% do not have electricity. In all the towns there is electricity, there is no fixed telephone and people have cell phones for personal use, but internet and telephone service is only available in certain point of the zone (mainly in schools).

Most of the communities of Acoculco are connected to each other by dirt roads where public transportation regularly circulates to Chignahuapan. The roads within the communities are generally in poor condition, and some people's vehicles, mules, horses, and carts travel through them. No ejidal population has sidewalks or sewers.

Some homes are built with materials such as brick, block and roofs such as tile or concrete. Others have kept their houses made of wood and cover the holes with plastic bags and tarpaulins.

5.2 Brownfield

5.2.1 Socioeconomic status

According to the National Council for the Evaluation of Social Development Policy (CONEVAL) and the National Institute of Statistics and Geography (INEGI), in 2010 Chignautla ranked among the municipalities with the highest percentage of its population living in poverty. In that year, 63.3% of its total population was poor, that is, 19,151 inhabitants found themselves in this situation; of which 24.7% -of those 19,151-, 6,379, was in extreme poverty (21.08% of the total population) and 66.69% (of 19,151 inhabitants) (12,772) in moderate poverty.

According to the information, we observe a predominance in the vulnerable population due to social deficiencies in 77.64%, of which 42.85% of the population has three or more social deficiencies, likewise, according to the indicators the greatest social deficiency is in the social security service where 68.28% of the population does not have access to this service, and 40.9% do not have access to health services, there is a 31.4% educational gap, and 38.3% do not have basic services in housing, there is a 19.7% without problems in food.

The lack of territorial planning has led to high degradation of natural resources and vulnerability of the population. As a consequence of this problem, there is a need to incorporate planning techniques in the management of natural resources and the occupation of the territory. The increase or decrease in environmental problems is associated with the growth and relationship of natural resources.

5.2.2 Core Services

Los Humeros has 119 dwellings, 80 of which are inhabited, but only 72 have floor coverings, 78 with electricity, 75 with piped water, 38 with drainage, 80 with sanitary services; 5 with 3 or more occupants; the average number of occupants per dwelling is 5.2. it also highlights that 280 people are not entitled to health services; 41 houses do not have drainage.

In Los Humeros, the forest areas present a moderate activity of clandestine logging and the inhabitants reforest the areas they are logging, trying to avoid the loss of timber species, avoid soil erosion and consequently the loss of forest areas.

6. SUSTAINABLE DEVELOPMENT

6.1 Common aspects

Because of our work experience in Chiapas, Nayarit and Baja California, we have recorded that all communities surrounding geothermal plants and those where there is a possibility of developing a geothermal power plant, it is common for people to expect that because they are close to the plant, it will provide free electricity to the immediate neighbors.

In the same sense, secondly we have heard that the inhabitants expect to be given a preferential price for electricity. In their expectations, in places where a geothermal power plant could be built the same thing happens and the inhabitants ask to be provided with free electricity.

On one occasion a person who worked at the CFE, and who accompanied us during ten days of fieldwork, explained to the population that this was unlikely because CFE is not who collects the money for the electricity service nor establishes the prices. The confusion arises because the electricity bill shows the name of the CFE and not the name of the Ministry of Finance and Public Credit, an institution that does establish the fees and collects the money from electricity consumption.

6.2 Main concerns

The main issues of the communities in the geothermal areas were current direct uses of space and geothermal resource, forests, water, mining, authorities, local leadership, criminal groups and relationship with the geothermal project.

In the greenfield, the process of change for the development of geothermal energy in the region will imply concerns of various kinds, since they will compete for the use of the same space and the same resources. The use of goods considered as common has never been free of concern (Hayden, 2003).

Geothermal heat and steam are the only resources that will not face this competition since they have never been used in the area of study. As described in the literature, this process of change is unpredictable, and what is possible to anticipate is that the origin of concerns will change with the passage of time, the stages of development of the new technology and the transformation processes of the surrounding population (Li, 2015). Against this background, it is important to recommend that the project maintain a position of permanent dialogue with the communities because the elucidation of concerns will also be a priority for the inhabitants, not only for the companies that pretend to use the geothermal resource.

In the brownfield, an important part that can cause concern is how the Federal Electricity Commission (CFE) and its employees perceive the social development. For example, in Los Humeros there was a resident who wanted to use geothermal water for agricultural irrigation, but his proposal did not resonate because CFE's position is that they don't want more neighbors. They do not want to promote successful businesses or applications that attract more people to an area where the relationship with the community could be affected. They want as little attention as possible. This poses a limited development scenario that would contrast with what the locals would want. Indeed, more families have come to Los Humeros during the 28 years of operation of the geothermal power plant.

6.3 Social needs

Pérez and Montenegro (2015) indicate that the territorial development approach is a strategy to combat the problems of the rural milieu, primarily poverty. To this end, a set of actions and programmes must be designed that have the territory as their intervention unit to manage rural development.

In this sense, it is necessary to diagnose the territory (as a group of localities) in order to identify if there is appropriation of the society of the geographical space, if a social construction is recognized. As well as, the close existence of space-subjects, where the latter practice of social relations (of power, mercantile, friendship, etc.). Likewise to be able to identify general lines of the behavior of the actors, of the organizations and of the environment (Saquet, 2009; Haesbaert, 2007; Bozzano, 2009 in Perez and Montenegro, 2015).

From the legal framework, from December 2001, the day the Sustainable Rural Development Law (LDRS) was published. There is a primary legal reference for actions aimed at promoting rural development in the Mexican Republic. In Article 4, this norm establishes as a priority the "promotion of productive and social development activities carried out in the various regions of the rural milieu, seeking the optimal use, conservation and improvement of natural resources, diversifying productive activity in the countryside, including non-agricultural, to improve productivity, profitability, competitiveness, income and employment of the rural population" (SAGARPA, 2001).

Training, advice, infrastructure and equipment are needed to transform raw materials and make them more valuable, but financing is essential to detonate production and improve productivity. It is necessary to lower costs, improve yields, sell better and raise incomes to be more productive (Jiménez-Merino, 2010).

6.4 Economic interests

Buendía-Martínez and Côté (2014) argue that rural economies should be transformed to be less dependent on agricultural activities, in the case study, the territory does not depend on this economic activity, however if there is an unskilled labor force, it is therefore presumed that it can be classified as low productivity. This scenario hampers the territory's ability to increase household income through the business fabric.

An alternative according to Buendía-Martínez and Côté (2014) are the regional development cooperatives (CDR) which represent a successful public initiative of collective generation, with important effects on the entrepreneurial diversity and on the employment of the rural regions of Quebec, Canada.

Within the wide range of legal formulas that can be used to achieve the reactivation of rural areas, cooperatives are an appropriate mechanism to ensure an integrated development. Since they make it possible to take advantage of indigenous resources by fostering regional cohesion, contributing to the development of democratic behaviors and reinforcing the interest of the community (European Communities, 1988 quoted by Buendía-Martínez and Côté, 2014).

Rural development must not only improve economic opportunities, but must also achieve the well-being of the population and the protection of socio-cultural traditions; this involves the design of integral, dynamic and complex processes that involve different sectors of the population (Coque, 2005 in Buendía-Martínez and Côté, 2014).

Space, characterized by some as a territory and not as a region, ceases to be a container of resources, elements, people or activities and constitutes a fundamental part of the transformation of related agents and territories.

Territorial development, detached from an administrative geographic space (national, regional, local, municipal), will be that development that incorporates diversity and difference as central elements of its strategy; "that assumes value judgments [...] indispensable in contemporary planning and that answers questions such as: who benefits directly from this strategy or vision? and how can it be implemented precisely in each place? independently of its dimensions or institutional delimitation (Ramírez-Velázquez, 2011, in Peroni, 2013, p. 62).

6.5 Environmental importance

In both zones there is a wide area of pine forest that has suffered lost in the last 24 years, transformations of the land uses have been shown, independently of the development of geothermal energy. This behavior responds to the economical need of the communities to develop using the natural resources available. The lack of territorial planning has led to high degradation of natural resources and vulnerability of the population. Because of this problem, there is a need to incorporate planning techniques in the management of natural resources and the occupation of the territory. The increase or decrease in environmental problems is associated with the growth and relationship of natural resources.

Among the factors that have contributed to the destruction of the ecosystems, the deforestation of forests, the change of land use for agricultural activities and subsistence hunting stand out. The inhabitants of the region are favored by the existing condition in the natural and forest resources since they obtain from them the production of goods and services that serve to satisfy the basic needs and to be able to carry out the productive activities for their subsistence.

One of the consequences that affects the population due to the growth and demand of the timber resource is that producers recognize the need to establish management programs for sustainable use not only in the use of trees but in the restoration, fire control and preservation of biodiversity. The rehabilitation of deforested areas favorable for the establishment of forest plantations to activate the potential for tourism development in the region. With this action, new sources of employment and income for forest producers could be achieved.

7. CONCLUSIONS

This works gives an idea of the complexity to develop scenarios of sustainable development, where the environmental, social and economic aspects are considered. However, it represents the beginning of inclusion of all these aspects and shows how a greenfield has the same concerns as a brownfield and how can we learn from the experience of a brownfield, to minimize risks in a greenfield. Even though the technology has developed in the geothermal industry, the same social and economic concerns appear. The most important thing to consider in a geothermal development is to maintain social integrity, biological diversity and ecosystem services.

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