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The Future Potential of the Silali Caldera, North Rift, Kenya

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ABSTRACT

Calderas exhibit natural landmarks and beautiful landscape in geothermal potential areas in Kenya rift valley. This important geological phenomenon is a remnant of volcanic eruption upon ejection of lava and debris under high pressure and temperature through lines of weakness in the earth crust to the surface resulting in partial or complete emptying of the magma chamber below it.

This paper aims at unveiling possible economic benefits associated with Silali caldera and its surroundings for the resident communities and the country upon further development while preserving its natural form as a geo-park. The main findings include high possibilities for power production, direct use applications, agriculture, tourism, sporting, and research. To harness the mentioned and many more potentials in near future it's recommended that connectivity of road networks, water and telecommunication infrastructure be finalized before drilling commences.

1. Introduction

The Eastern branch of the East African Rift transects through Kenya along the north-south direction. The sigmoidal super trench has about 40-60 km E-W breadth and 1200 km N-S spread with an annual drifting rate of about 0.5 mm, Saemundsson, (2010). The active nature of the rift is continuously enhanced by creation of new faults yearly as the rift parts and fluid-filled fractures induces micro-seismicity and opens up more fractures in incessant cycles. These further causes thinning of the earth crust along the rift floor and development of line of weaknesses through the faults that eject lava to the surfaces, forming chains of eruption centers on the rift floor. Some of this volcanic centres host large caldera systems.

Among the eruption centers in the Kenya Rift the main caldera systems include; Barrier, Silali, Paka, Menengai, Longonot and Suswa volcanoes. These sites besides their beauty attract a lot of interest from different disciplines due to their potential for geothermal resources and environmental sanctuary for native flora and fauna. The aim is to preserve the natural landscape and diversify its potential use for economic gain to the country and the resident community to enhance its conservation.

Silali geothermal prospect located in the North Rift encompasses Silali caldera. Despite completion of exploration phase, the prospect was yet to be developed by drilling to harness much needed power and direct use application associated with thermal fluid returns. However, currently

Geothermal Development Company (GDC) has shown kin interest in developing the Baringo-Silali block prospects, improving roads, water pipelines, well pad construction all at advanced stage and soon may start drilling. These will be the beginning of Silali and generally North Rift block opening up for business attracting other aspects of economic prospects described in this paper.

2. Work Done

2.1 Geoscientific Exploration

Geoscientific exploration was carried out by GDC between 2010 and 2016 and by KenGen in 2007. The outcome revealed great potential for existence of geothermal resource in Silali-Baringo block. The study further indicated greater potential in form of direct use application from the power production.

2.2 Water Sources

Silali is hot and dry most part of the year, with no surface water sources except during the rainy season which is short-lived due to high rate of evaporation, exposing the community living around it constantly to high demand for the precious liquid for their life support. Permanent sources of surface water close to Silali are L. Baringo about 74 km to the south and River Suguta 20 km to the north-northwest. However, the area around Silali at least 10 km radius from caldera is scattered with boreholes and water pans for the community in addition to ephemeral streams that collects storm water during rain.

The current development in the area entails extraction of water from L. Baringo for communities living in the area and soon the Lake water will find its way to the summit of Mt. Silali and quench nomads thirst at the floor of the caldera, credit to Geothermal Development Company Limited. Water at Silali caldera summit is a magnet in enhancing and accelerating future development possibility plans for the caldera discussed above. Figure 1 is an indication of work in progress by Geothermal Development Company (GDC) in construction of water pipeline for the community and drilling project in Silali, Paka and Korosi geothermal prospects. Water for the community use will be cleaned to the potable standard and distributed at several points away from water storage tanks for drilling intake.

Alternatively, *fumaroles water harvesting* could be developed as a potential source of water for the community where the lake water cannot reach if it passes the safe drinking test.

2.3 Access Roads

Part of preservation of Silali caldera natural aesthetic and value addition to the travel through Silali, is a proposed construction of an underground tunnel drilled 10 km from the base of the mountain in the south emerging at the caldera floor to avoid destruction of the caldera ring structure, probably along a fissure. Upgrading and tarmacking Cheseremion- Naudo road that feeds the tunnel will further open up the area for more business and development. Construction of road networks between several geo-parks in and around Silali for easy access as well as making designated footpaths and trails for hikers, riders and bikers.

Recent infrastructural work by Geothermal Development Company in this area (Figure 1) has opened up Korosi, Paka and Silali, with murram roads that reaches constructed well pads shown in Figure 1. However, once drilling commences and more wells sited, the prospects access will improve and geo-sites will be connected with accessible roads for geo-tourism and community easy access in future.

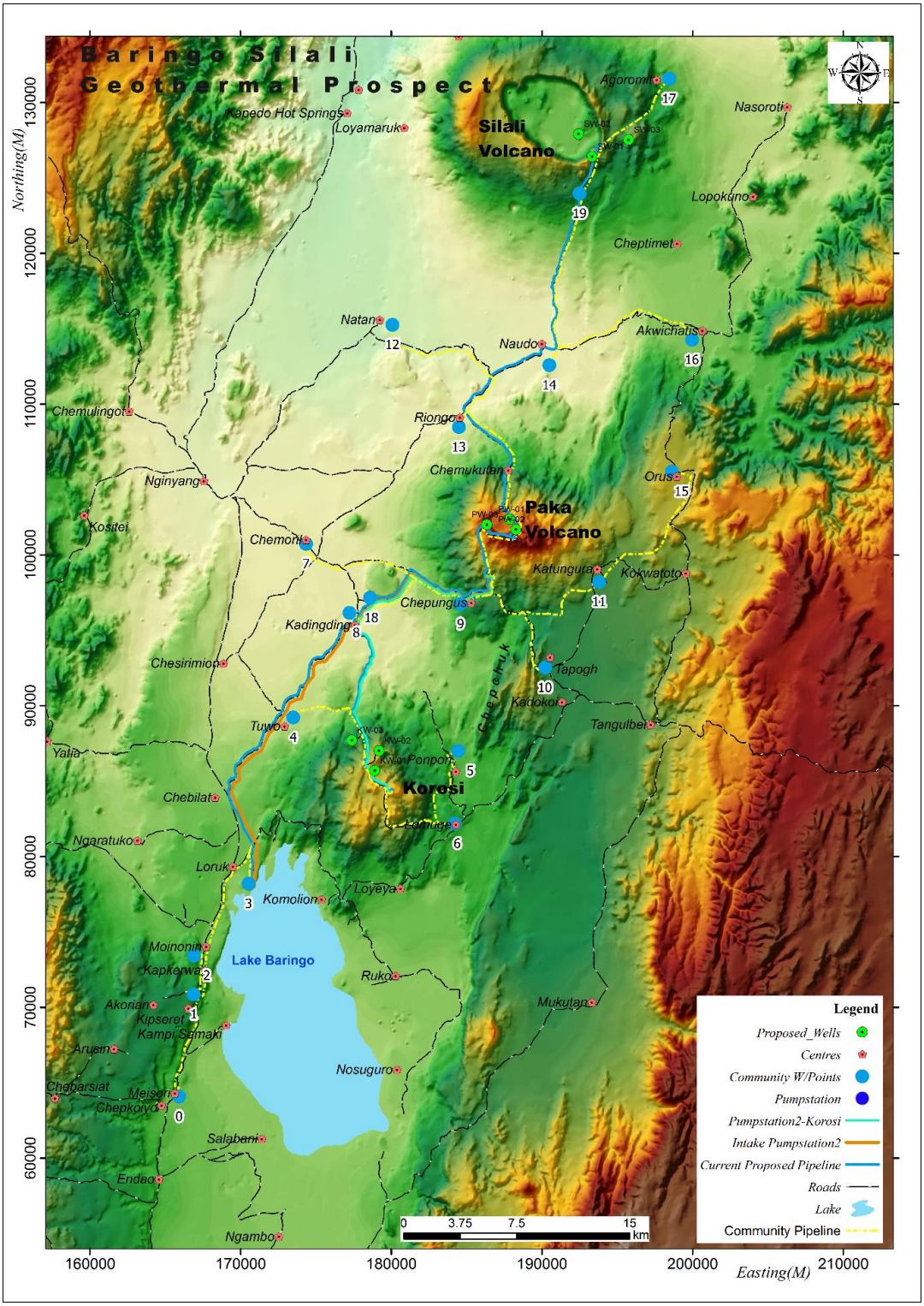

Figure 1: Waterline and access roads from Lake Baringo to Silali Prospect

3. Caldera Types and Formation Mechanism

Calderas are out-sized volcanic craters formed by either eruption of explosive volcano or collapse of extrusive material into emptied magma chamber. Roche et al; (2000) associates Caldera formation in terrestrial and other planets to tectonic settings during large ignimbrite eruptions and by the collapse of shield Volcanoes. During which a large volume of magma is evacuated explosively in the form of pyroclastic fallouts and pyroclastic flows, Druitt and Sparks, (1984) and

Aguirre-Díaz, (2008). A collapsed caldera forms when a crustal block above a shallow magma chamber collapses, Aguirre-Díaz, (2008). The collapse happens when magma chamber is emptied through volcanic eruption or lateral subsurface magma movement, causing the unsupported remnant rocks that form roof of the magma chamber to cave-in forming large crater (Figure 2).

Explosive calderas form when large magma chambers loaded with silica-rich lava and ample gas rise from subsurface. Highly viscous silicic magma traps gas bubbles under high pressure at depth below surface. The gas expands due to pressure reduction as the fluid rise to the surface causing huge explosion that blast away large volume of rocks and magma to form caldera. Degassing of the injected superheating felsic magma can sufficiently cause over-pressurization of the chamber and trigger caldera-forming eruption due to volatile release and separation of vapor phase, Troll et al., (2000). Troll et al., (2000) further indicated possibility of caldera floor resurgence due to overpressure from degassing basic magma within the refilled chamber.

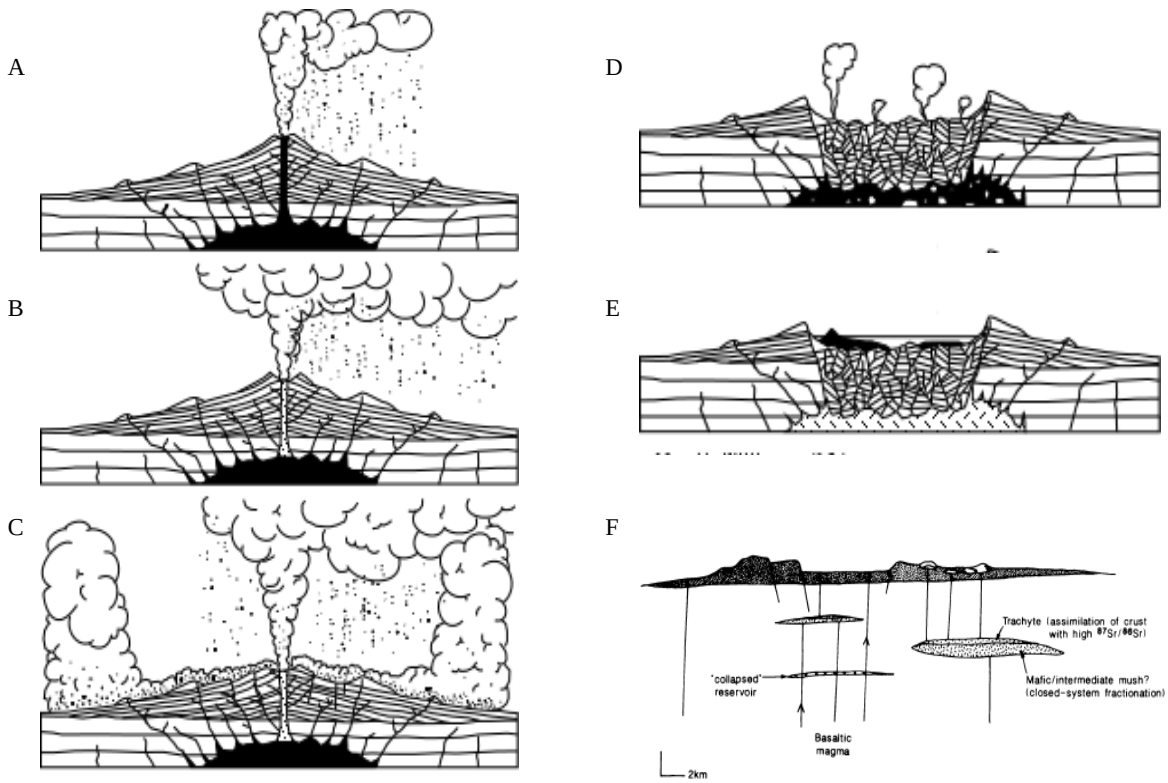

Figure 2: Caldera formation stages. Modified after H. Williams (1951) and Mac Donald et al., (2006)

4. Economic Potential of Silali Caldera

With a slight development and infrastructural upgrade without destroying the natural beauty, Silali and Paka volcanoes and their caldera environment can mend the regions fragmented economy, which is marred with banditry and negative stereotyping to a land of hope and opulence for the county and resident community. This is so because of the resource potential available in this bush-land under the scorching sun as described below;

4.1 Community Reserves

The Silali caldera and Mt Silali in general could improve the livelihoods of the communities residing around the area once upgraded to a community reserve and conservancy area, under which they can herd their livestock and protect the environment from any other form of degradation from its current pristine nature. This can be done through community or county controlled project that collect fees; for accessing the area, site seeing and sporting. The

communities can also open cultural centers with community museums as part of preserving the traditions for the next generation and anthropologist interested in learning and documentation of these cultures. In addition to the cultural museums a snake museum can attract a large number of visitors to the area for research since the region is known for venomous species of reptiles in the area, where venom can be extracted to manufacture antivenom products that will benefit the community against snake bites which is quite common and fatal. Snake farming could be projected from the research outcome if successful for mass production of multibillion industry pharmaceutical spit sap.

4.2 Security

Development and economic growth directly depends on sustainable peace and security among the communities leaving in the region over available resources as well as individual wellbeing of the resident communities. Poverty reduction or eradication using bountiful resources in the region once developed will create jobs for the locals and improve their livelihood. Through involvement and inclusivity of the community in the projects, they will own it and provide the much-needed security for the investment. The insecurity and aggression will cease once the communities integrate in the work place and experience the fruit of what Silali offers, through arid agriculture to enhance food security and other jobs from direct utilization of geothermal, geo-sporting and geo-tourism.

4.3 Native products

The community domesticates camels, cattle, sheep and goats for milk, meat and hides in addition to donkeys for transport in pastoral settings. Marvel of man integration and adaptation to the environment is clear from supplemental use of what the wild north offers the native residents. These come inform of wild fruits, aromatic fruits and leaves, edible roots, gums and resins, sisals, honey, medicinal herbs and roots, all of which if developed and commercialized will improve the local economy.

4.4 Geo-tourism

Silali caldera is an oval shaped smoothly curved gigantic depression with a generally flat pyroclastic floor and a stunning view from the caldera rim or by flying over. This attracts both locals and international tourists interested in witnessing breathtaking natural beauty in the midst of the conventional wild north rift. In addition to caldera, other interesting areas in the neighborhood to visit include immediate north of Silali massif with salty Lake Kalnangi sourced from Kalnangi and Akiloset hot spring at the foot of Silali to the north, as it drains its super alkaline fluids to the Suguta valley. Sourced from Kapedo hot spring, river Suguta bounding Silali to the west meanders in a gorgeous Suguta valley landscape. Northwest and West of Silali host Lorusio and Kapedo hot springs respectively. Silali has huge fissures mostly aligned in north-south directions and young lava tubes worth visiting to understand the genesis of the volcanic eruption. South of Silali caldera also exist a mini caldera locally known as "*Ketenmenning*" with a vertically deep perfectly circular eruption vent and volcanic bombs fragments in the neighborhood. Several other mini calderas, craters and cinder cones are common in Silali.

The eastern side of Silali caldera is endowed with huge fissures, faults, young lava flows and high-pressure fumaroles that attract visitors of all backgrounds including researchers and students (Figure 3).

South of Silali is Paka volcano, with a spectacular nested caldera at the peak, parasitic cones at the flank of the volcano and maroon shades of slopes attributed to geothermal clay alterations. There are hot and steaming grounds especially at the floor of the main caldera and its inner crater. Thus, interconnecting these places of interest through road network will open up the area as an economic block to the further north

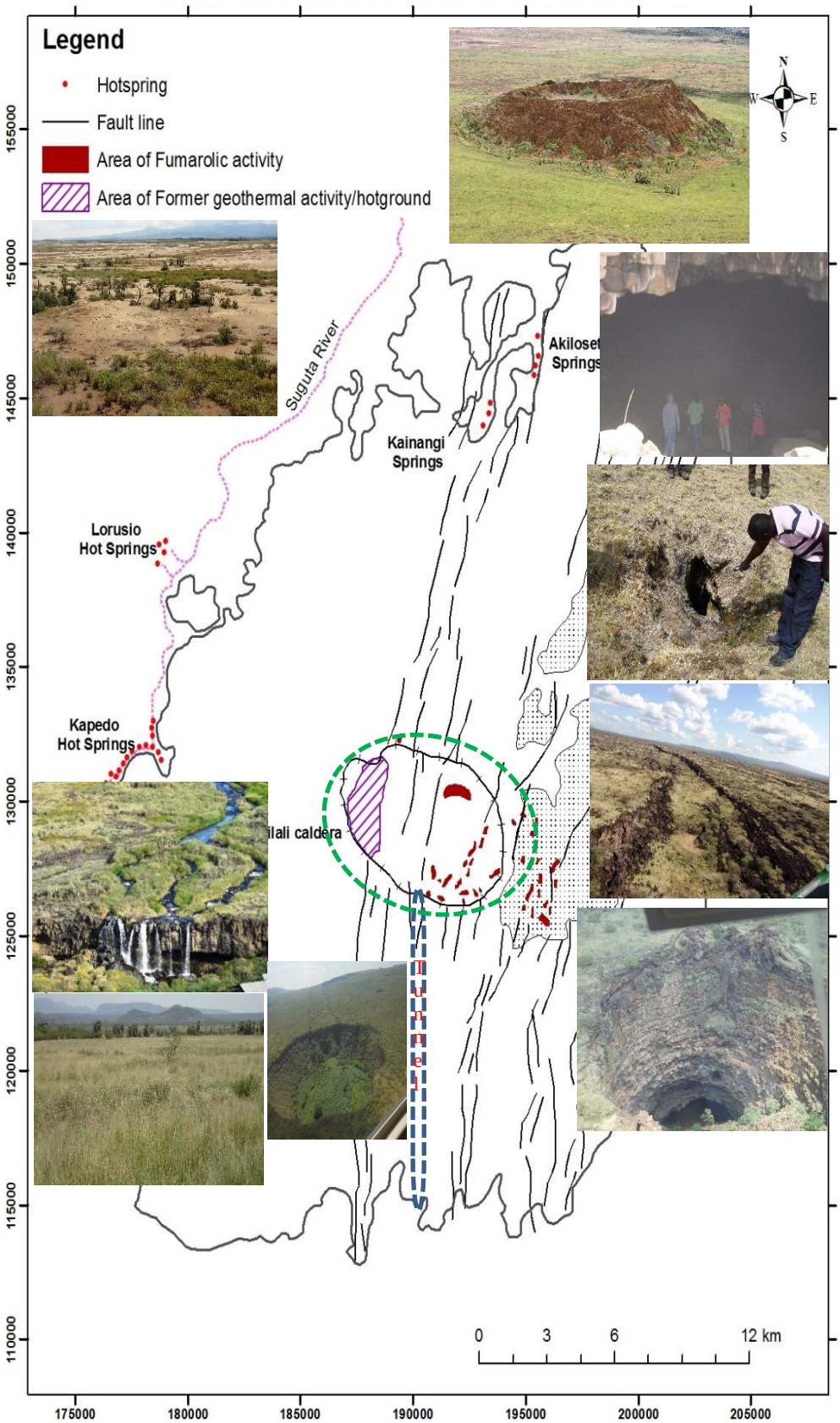

Figure 3: Geo-interesting sites around Silali caldera

4.5 Geo-sports

Caldera been at the summit of the greater Silali volcano has highest altitude of 1528 masl Lagat and Muturia, (2011) at the rim and stands about 400 m above the caldera floor. Measuring 7.5 km by 5 km with near perfectly oval natural architecture, it makes a great site for *para-gliding* and *skydiving* a long its 7.5 km length and 5 km breadth with a full view of the gigantic Silali eruption vent.

Sports such as *zip line* and *aerial tramway* riding can be awesome sporting activities across the breadth and length of the caldera rim at pay per ride. The caldera floor is a great site for shooting films with high speed cameras loaded overhead multilane zip lines and hanging cable-car routes, which can be a good source of revenue for the locals and the park in general (Table 1).

Alternatively, a slight modification can be made a long the inner wall of the caldera ring and installed with rails and *orbit vehicles* in a 360° super speed travel merry go-round around the caldera powered by geothermal energy generated from this field in near future.

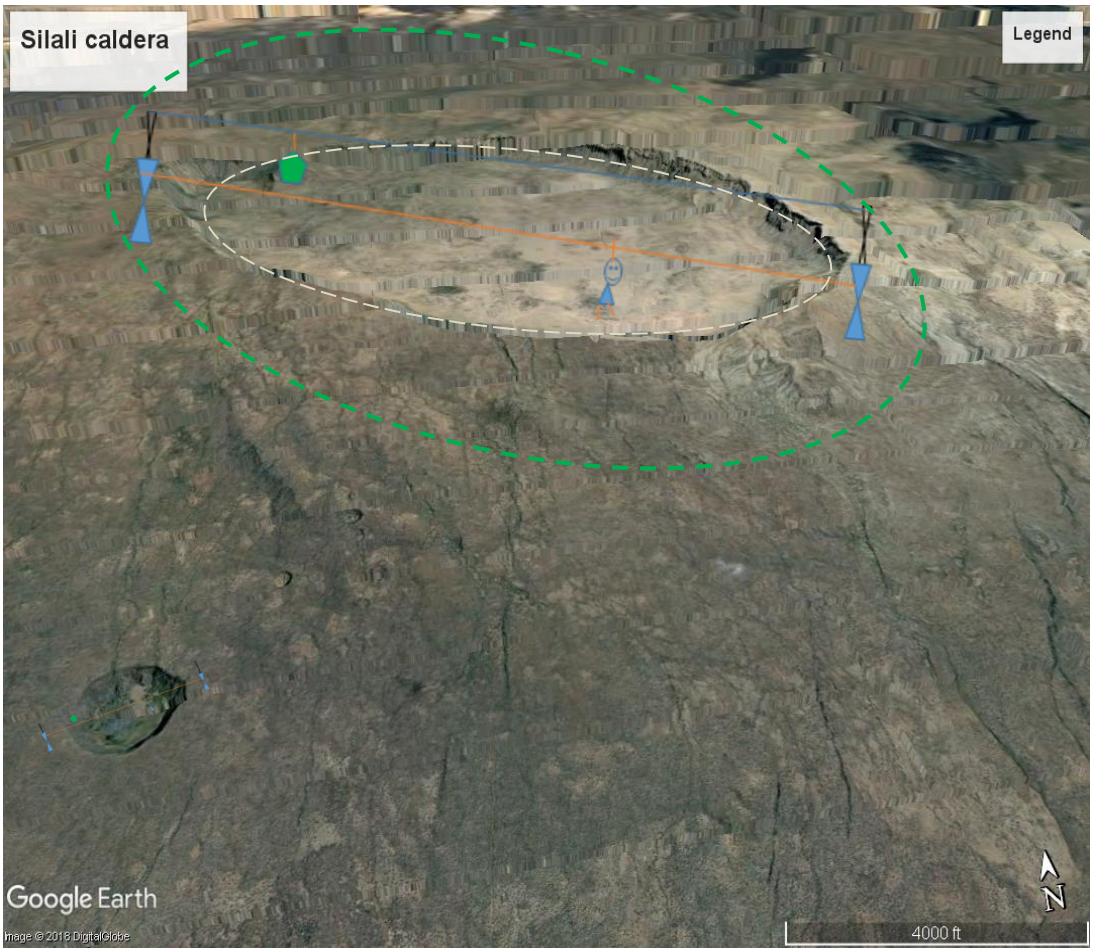

Figure 4: Zip lining, aerial tramway, inner caldera orbit and outer hiking route across and around Silali caldera

The inner wall slope of the caldera can also be modified into sitting arrangement for spectators and fans and the floor upgraded into a large stadium that can accommodate most sporting activities.

Outside the caldera a well paved footpath could be made around the caldera for *hiking*, *biking*, *riding* and *nature walk*. This will further add to the economic scale of Silali by providing job opportunities for the local tour guides (Figure 4).

Table 1: Total estimated annual revenue from 100,000 visitors spending in geo-sport and tour

Geo-sport Activities	*Charges (USD)/Person*	*Estimated Annual Visits of 100,000*	*Annual Total Revenue (USD)*
Reserve Access	30	100,000	3,000,000
Paragliding	10	5,000	50,000
Skydiving	10	5,000	50,000
Zip lining	10	25,000	250,000
Aerial tramway	10	50,000	500,000
Caldera Orbit	10	50,000	500,000
Camel ride	10	2,000	20,000
Biking	10	500	5,000
Silali tour	50	100,000	5,000,000
Total			*9,375,000*

4.6 Geo-industrial parks

Endowed with huge potential for geothermal energy, Silali can support huge industries especially those associated with readily available raw materials in the area. These include meat and milk processing and preserving, hides and skin processing, aloe Vera plant processing, honey processing and agricultural products generated through irrigation from Natan Plains, Naudo plains, Suguta valley-kasarani plains near Lomelo, Nasorot-Akwichatis bound plains and several other agricultural potential sites around Silali. Given these ideas are put into practice for the sake of the resident and county, hunger and drought will be a thing of the past for the residents and the life style will be improved for the next generation from pure pastoralism to mixed farming. This will further bring about paradigm shift in lifestyle and an end to cattle rustling menace that dwarf the regional peace, growth and development. End result will be reduced but quality livestock farming, proper land use and management, increased literacy level, improved health and minimal frown upon obsolete cultural practices.

4.7 Employment opportunities

Silali will open up for businesses internationally, nationally and locally. It will attract international investors in harnessing the geothermal power and nationally investment in building industrial parks and high end-resorts around the caldera utilizing the power produced. The tour companies in the country will add a new frontier in travel destination boosting economic position of the Kenya while creating jobs locally. Been on the world map as an integrated research center for renewable energy, arid agriculture, livestock husbandry, anthropological museum, locally available botanical and zoological products value addition which will create employment opportunities for regional and local communities. Sporting activities such as skydiving, paragliding, zip lining, aerial tramway riding, biking, hiking and camel riding at the caldera and around it will create jobs for the locals as well and generate income for the county.

The local population and households around Silali (Table 2) per 2009 census is an indication of the population that can directly benefit in terms of jobs and power connection where permanent settlements are availed. The active working age bracket in Silali of between 15-64 years comprises of 52% male and 48% female population in the area GIB Africa, (2018). The number of people employed in the Baringo County where Silali is located is 190,349. Those seeking employment are 30,348 while the economically inactive are 210,822 CIDP, (2013). Out of the total labor force in the Baringo County, only 32% are employed and the rest 68% are unemployed. The main source of employment in the county is wages, making about 34 % of the total employment CIDP, (2013).

However, once Silali-Baringo geothermal prospects become fully functional, the employment rate will increase.

Table 2: Demographic characteristics of the area based on the 2009 census Lagat & Muturia (2011)

Division	Area (km^2)	Locations	Sub-location	1999	Population	Population Density	No.of Households
Kolloa	1327.1	6	14		23,782	14.09	3,741
Tangulbei	716.4	4	11	19,505	19,031	20.89	2,994
Churo	328	3	7		11,914	28.89	1,874
Nginyang	1097.7	4	11		19,089	13.68	3,003
Mondi	1055.6	3	9		28,425	20.25	4,276
Total	4,524.8	20	52		101,000	17.56	15,888

Table 3: Distribution of the Population by age groups in the Silali Area, GIB Africa (2018).

Project Area	Gender	Age group			Total
		0-14	15-64	65+	
Silali	Male	58.8%	51.6%	85.7%	54.9%
	Female	41.2%	48.4%	14.3%	45.1%
	Total	100.0%	100.0%	100.0%	100.0%

4.8 Energy potentials

Geothermal researchers estimate energy potential of the Silali conservatively to over 800 MW_e Lagat and Muturia, (2011) from geothermal alone which is the main attraction to this region currently. However, the energy potential in Silali and it's environ is limitless from other mixes of renewable sources. Located in arid region of the country with sunshine in most days of the year, Silali is one of the best regions in the country where solar energy production can boost the energy mix in the country. Harnessing geothermal power in Silali will be in phases. The first phase with at least 200 MW_e connected to the grid will be enough to support all power connections in the Baringo county and its direct use industries. The current electrify connection stands at 10,400 CIDP, (2013) and needs to improve with new power connected to the grid and reduced tariffs to the locals and the country.

5. Conclusion

Geo-economics of Silali caldera once fully developed is unimaginable in terms of employment, research and energy hub. If the geo-sporting activities and tours alone could fetch Silali geo-park USD 9,375,000 for estimated 100,000 visitors, the other aspects of industrial parks and direct use of geothermal energy for processing and preserving industries from local products to high end resorts will fetch billions of dollars for the area annually. North rift geo sites is the next tourist destination equivalent of Masaai Mara and Serengeti, that counties involved and investment gurus should take note.

The forecast economic benefits that come once power generation take effect include reduced electricity tariffs to the citizens and direct use application in processing and preserving industries, especially for the abundant animal products. The direct use application will support agribusiness in the region and small scale fruits, vegetables and fish farming under controlled temperature for improved quality and maximum production.

Improved socio-economic standard with power generation and direct use application will lead to shift in the mode of living from pastoral nature to permanent settlement which will positively impact on school enrolment and educational standard in the region. Crop production from irrigation of neighboring fields will improve food security not only to Silali residents but also to the entire north rift region and beyond.

Similarly, most of the above discussed applications can be replicated anywhere in the world and more so by the Great Rift countries endowed with these bountiful depressions called caldera.

Acknowledgement

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