Proposal of Crop Drying by Analysis of Grain Farms Within Close Proximity of Menengai Geothermal Resource in Kenya via Remote Sensing

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ABSTRACT

The direct use of geothermal energy is highly dictated by economics, thermal needs and the quality of thermal energy available. Several economic parameters that dictate the viability of direct utilization of geothermal resources are sustainable thermal energy demand, brine piping routes that encourage brine flow via gravity and an efficient flow rate of brine to match the thermal demand as well as short brine piping distances. The current research work analyses thermal demand near geothermal resources via remote sensing of agricultural activities and urban development. Clustering of crop types and crop-calendars will help analyze the viability of crop drying, greenhouse warming and aquaculture using geothermal energy. Urban density clustering aided in decision making on cascaded use of geothermal energy from industrial processing of agricultural goods to urban-heating and recreational spas. This research seeks to identify and match thermal needs to available geothermal resources via GIS mapping. The results show that the Menengai prospect is best suited for crop drying, industrial processing, spa and district heating. Priority being in that order.

INTRODUCTION

The concept of direct use (DU) of geothermal energy is not new in Kenya. From time immemorial, local communities living near geothermal have used fumaroles and hot springs as places of worship and for balneological purposes (Tole, 2002). Farmers at Eburru, near Olkaria geothermal field, have for long time been using steam from fumaroles to dry pyrethrum since 1937 (Ndetei, 2016). Besides, residents of Eburru and Suswa who reside near fumaroles condense the geothermal steam to provide water for bathing, washing and cleaning, Fig. 1.

Fig. 1 Different fumaroles being harnessed to condense steam in the Suswa area (Ndetei, 2016).

However, the most recent and economically feasible project of direct utilization of geothermal energy in Kenya is the use of geothermal energy for greenhouse heating in the Oserian Development Company, as illustrated in Fig. 2. A 2013 study report by Land O' Lakes showed that the Oserian flower farm reduced heating costs by 70% by adopting geothermal heating in greenhouses (Land O'Lakes, 2013).

Fig. 2 Geothermal heated greenhouse in Oserian Company, which grows various species of fresh-cut flowers for export.

Geothermal energy in Kenya can potentially improve Kenya's agricultural sector beyond greenhouse warming to crop drying, milk pasteurization, horticultural pond heating, chicken hatchery. Many geothermal resources in Kenya are located in remote arid or semi-arid regions with sparse agricultural activities and farther from fertile rainfed agrarian areas. This is a huge challenge when it comes to interlinking these geothermal resources to farming regions with high agricultural thermal demands due to long travel distances with almost no accessible routes.

The current paper focuses on the Menengai prospect and the surrounding arable lands to ascertain the feasibility of interlinking the two for crop drying and other cascaded uses, such as district heating in nearby Nakuru city.

GRAIN DRYING

Post-harvesting grain loss is a serious problem in Kenya, especially for maize, where it is estimated that 30% of the harvested grains are lost through poor drying and storage (Dudi, 2014). This affects the farmers economically and aggravates food security in a country whose demand for maize exceeds the local supply (Onono et al., 2013).

Other cash crops that require post-harvest drying include coffee beans, pyrethrum, tea, macadamia nuts, groundnuts and cashew nuts. The current trends in Kenya for drying crops are spreading grains on the ground and letting solar energy provide the thermal energy necessary for moisture evaporation. Since white maize and common beans grains have low surface solar absorptivity, about 0.5-0.7 (Arinze et al., 1987), and porosity of 35% (Ekechukwu and Norton, 1999), basic sun-drying on the ground can take one to two weeks for moisture to drop to the required 14% (O'Lakes, 2013). The prolonged drying periods on the floor expose the grains to bacteria, fungi and pests, which later lead to grain loss through spoilage.

To reduce the post-harvest loss of grains, areas near geothermal fields should take advantage of the low-grade energy in brine for hygienic and faster crop drying with reduced chances of grain loss. According to a research done by VEGA for USAID and GDC on demand for energy on crop drying, there exist some diesel-fired industrial maize dryers, one is located in Nakuru, which handle grains transported within a radius of 250 km (O'Lakes, 2013). This proves that the centralized drying centers concept is viable, and if the drying centers utilize energy in geothermal brine, they can save up to 50% on energy cost as compared to using fossil and biomass fuels (Ngethe and Jalilinasrabady, 2020).

MENENGAI GEOTHERMAL FIELD

Menengai is a late Quaternary caldera composed of various trachyte lavas located north of Lake Nakuru with an elevation of 1900-2000m above sea level at the floor of the caldera. Its surface manifestations occur as active fumaroles (with temperatures range of 62 to 88 °C) and steaming grounds (Kanda et al., 2018). The active faults seem to run in N-S and NNE-SSW as shown by **Error! Reference source not found.**.

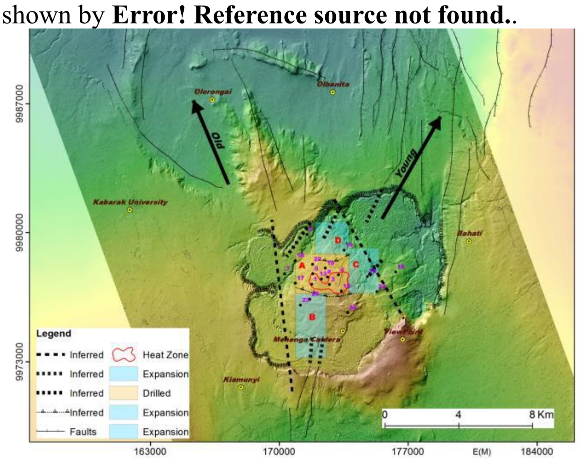

Fig. 3 Menengai crater's fumaroles and possible faults in the reservoir (Mibei et al., 2016; Kanda et al., 2018).

Menengai geothermal reservoir has a temperature range of 140-390°C depending on the location of the well's slotted casing relative to the boundary of the reservoir (Mbia et al., 2015). In this regard, the existing wells produce hot water, dry steam, or two-phase fluid. Some research suggests that there exist two reservoirs in this field, one shallow liquid dominated reservoir of temperature ranges of 130-210°C and a deeper vapor-dominated reservoir with temperature ranges of 330-390°C (Montegrossi et al., 2015). The reservoir depth varies from 0 to 1200m above sea level as shown in Fig. 4, though most production wells range from 2000-2200m from the floor of the caldera (Mibei et al., 2016).

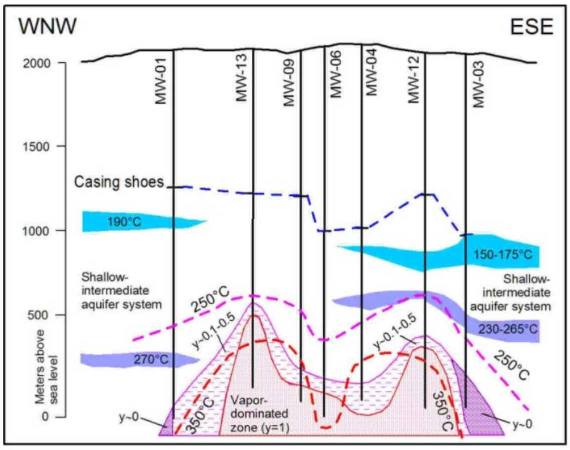

Fig. 4 A schematic cross-section of Menengai caldera illustrating a possible configuration of the reservoirs (Montegrossi et al., 2015).

The volume of the reservoir has not been estimated yet, but preliminary studies show that it could sustain 400-1600 MWe. Currently, there exists over 20 production wells and power plant construction by IPPs are ongoing to produce 105 MWe in the nearest future.

Available thermal resource

By the end of 2017, Geothermal Development Company (GDC) had drilled over 20 productive wells, four of which produced low enthalpy hot water at less than wellhead pressures of 2.5 bara and temperatures 111 - 127°C. The rest either produced steam or two-phase fluid with average wellhead pressures of 6 - 12 bara at temperature ranges of 159 - 187°C. Additionally, this field produced a total of over 800 t/h of steam and 900 t/h of brine from these productive wells. Since then, many more wells have been drilled resulting in additional flow rates of geofluids by the GDC. Since steam is utilized for electric power production, a percentage of brine could be harnessed for direct use as demonstrated by a pilot project in Menengai that experiments with greenhouse warming, milk processing, grain drying and aquaculture. Unfortunately, the direct use pilot project is situated in Menengai caldera, which is a government-protected zone, making it a challenge for nearby farmers to access the milk pasteurization and grain drying facilities.

METHODOLOGY

The current research seeks to find out the situation of grain farming within the vicinity of the Menengai prospect. Of importance is the size, density and proximity of the grain catchment region to sustain an economically viable grain drying plant near the geothermal prospect.

To accomplish this, sentinel-2 (platforms A and B) images were downloaded from https://scihub.copernicus.eu/dhus/#/home and processed to track grain farms since land preparation, grain planting to growing seasons thus extracting crucial information about crop-calendars and farm sizes.

Sentinel-2 images were downloaded twice monthly from 2020 January 1st to 2020 September 23rd and the crop growth monitored. Since the Nakuru region is a highland with an average elevation of above 1700-2000 m asl, it receives moderate to high annual rainfall, 900-2000mm, that encourages both forests and agriculture to flourish in the region. As a result, after a growth period of 4 months, the maize crop assumes a NIR reflectance similar to the surrounding forests and hence making it difficult to discriminate them apart by remote sensing until the maize leaves attain senescence, just before the crop is ready for harvest.

Image processing procedure

After downloading the images, several preprocessing procedures were performed in the following order;

1) Atmospheric correction through Dark Object Subtraction (DOS)
2) Cloud cover masking
3) Resampling of band B11 from 20m resolution to 10m resolution via near neighbour interpolation.

Consequently, bands B11 (SWIR), B08 (NIR) and B02 (Blue) were combined into a false-color composite image that highlights rigorous growing crops, such as maize, as bright green, bare soil and sparse vegetation as mauve, buildings and roads as light purple, lakes and rivers as bluish and mature trees as dull green to dark green (Lemenkova, 2020). Some of these false-color satellite images are shown in Fig. 5 to Fig. 8 for a small, sampled region in the study area.

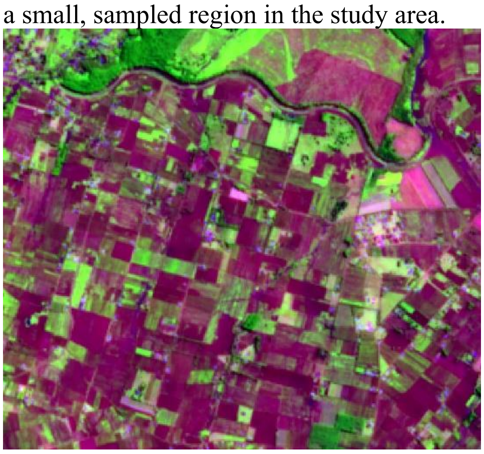

Fig. 5 Sentinel-2 image showing land preparation.

Fig. 6 Sentinel-2 image showing planting season after the onset of long rains.

Fig. 7 Sentinel-2 image showing a rigorous vegetative maize growth stage.

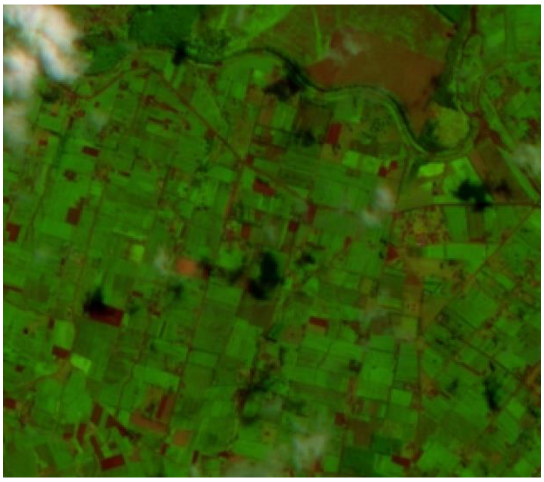

Fig. 8 Sentinel-2 image showing maize growth near the reproductive development stage, (*some clouds and their shadows included*). At this stage, the surrounding forests, bushes and maize farms adopt a similar NIR and SWIR reflectance that makes it difficult to tell them apart.

The false-color multiband images of sentinel-2's B11, B08 and B02 were then subjected to supervised land use classification. Support Vector Machine, (SVM), algorithms were used to extract information on maize plantation periods, maize farm sizes, maize farm distribution, cluster sizes of nearby human settlements, and also interconnecting roads through segmentation and classification methods (Varma, 2016).

To confirm maize farm sizes and distribution, processed images of different dates were subjected to change detection and those regions that showed little or no change during were regarded as bushland and grasslands in between the maize farms. The counterchecked classified images were reassembled to form a harmonious uniquely paletted image highlighting maize farms in their true sizes and distribution.

RESULTS AND DISCUSION

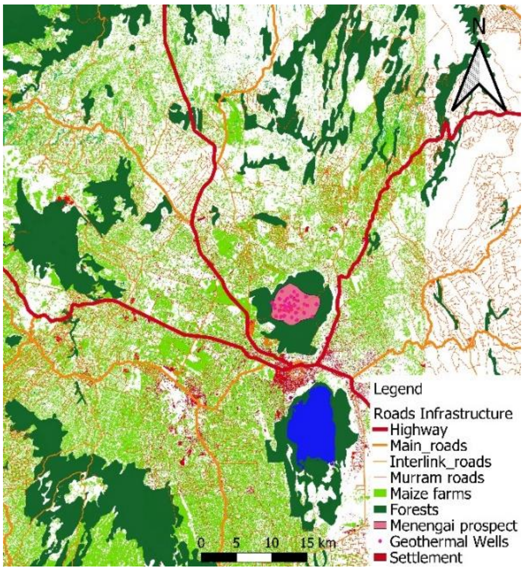

Fig. 9 Distribution of maize farms within the vicinity of the Menengai geothermal field.

Fig. 9 shows a maize catchment area of 4800 km^2 within Nakuru county. The main access routes through maize farms are highlighted in addition to Nakuru city and its smaller surrounding towns.

From Fig. 8, it can be inferred that the maize farm distribution is not uniform as the farms are smaller and sparse to the northern and eastern side of the Menengai geothermal field than those on the western and south-western regions. Another unique information that was extracted from this research is that planting seasons begin in early April for the eastern regions, and nearly two months later for the western regions. This means the harvesting will also stagger by two months and this is a good thing to allow a grain drying plant to run at a modest capacity.

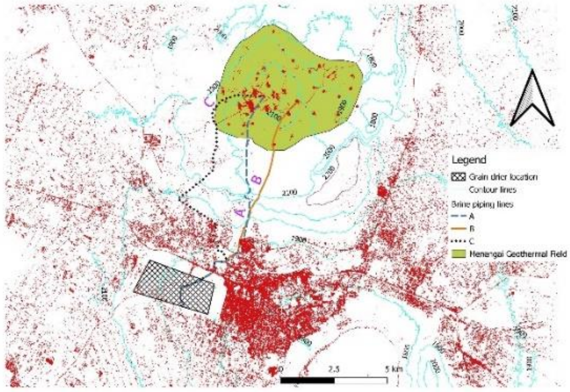

Fig. 10 Proximity of Menengai prospect to the Nakuru city with proposed geothermal heated grain drier location in the hatched polygon.

The immediate western regions of the Menengai geothermal field have huge tracks of land growing maize and wheat while the southern-western regions have moderately sized farms that are densely distributed. These are the critical regions that could serve as grain catchment zones for a geothermal grain drying plant, though their feeder-roads are murram roads hence they are difficult to pass through during heavy rains.

From this research, a feasible location for a grain drier using geothermal energy in brine is suggested with three different brine piping layouts A, B and C as shown in Fig. 10. The differences in the proposed brine piping routes are their lengths and the elevation at which they cross the caldera rim as Fig. 11 shows

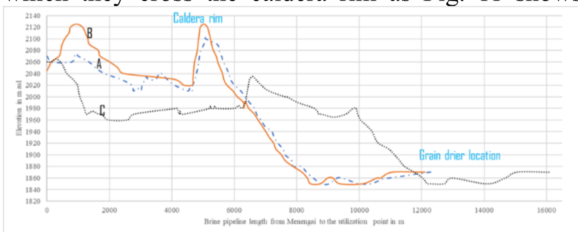

Fig. 11 Difference in lengths and layout of the proposed brine piping A, B and C.

As is a piece of common knowledge, the longer the piping line, the more is the installation cost and increased heat loss. On the other hand, the pipe that climbs a steeper slope runs at risk of encouraging a faster rate of silica scaling, especially under low-pressure flow regimes and also increased operational costs from brine pumping.

District heating

Since the grain drier will have a downstream of 50-60°C of brine, this heat can be utilized in a cascaded manner in district heating, swimming pool heating and spas. Fig. 12 and Fig. 13 show the lowest and average temperatures during the cold rainy seasons of April to August around the Nakuru region.

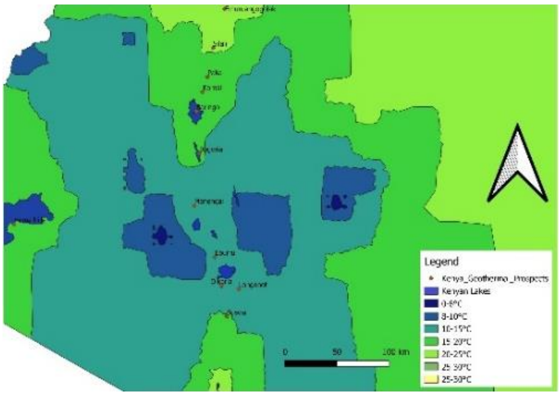

Fig. 12 Lowest weather temperatures around Nakuru county from April to August.

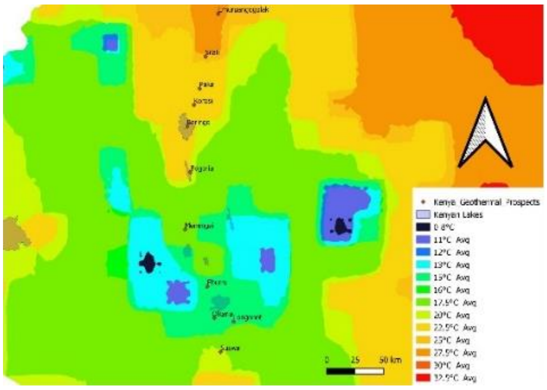

Fig. 13 Average weather temperatures around Nakuru county from April to August.

During the cold months of April to August, Nakuru experiences cold nights of temperatures 10 - 15°C and daytime average temperatures of 15 - 17.5°C. These low temperatures provide an opportunity for geothermal district heating and associated activities such as spas and heating of swimming pools, which have the potential to encourage tourism in the region.

CONCLUSION

The current research has used remote sensing to visualize the sizes and distribution of maize farms around the Menengai geothermal field. Menengai prospect has a rich and sufficient maize catchment to sustain a commercial geothermally heated grain drier. The initial cost of the drying plant will greatly depend on the brine piping route chosen as well as the capacity of the plant. Due to the proximity of the proposed drying plant to Nakuru city, the weather analysis of the region calls for district heating and other associated heating purposes such as spas and swimming pool heating. Besides, the region is well served with a good network of roads that will enhance quick transportation of produce from the farm to the drying plant and later to the market, Nakuru city being a key market.

Brine routes A and B run adjacent to Nakuru's industrial zone where the manufacturing of soaps, cooking oil, milk chilling and so on take place. All these are processing plants with huge thermal demands that could utilize the hotter brine for industrial processing before it is cascaded to the grain drier and eventually to the district heating system. Indeed, the Menengai prospect and Nakuru city have the potential to become the most successful cascade direct use of geothermal energy in Kenya.

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