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VEGETATION TYPES AND DIVERSITY IN MENENGAI CALDERA GEOTHERMAL PROJECT AREA, KENYA

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ABSTRACT

The study was aimed at documenting the vegetation types in the Menengai Caldera. Line transects were established in each forest type and used as baseline upon which sampling plots were located. Plots of 20x20 m were placed at intervals of 50 m and marked along the transect and used to quantify species distribution patterns and vegetation dominance. Each block was divided into 4 (10x10 m) small plots within which vegetation parameters were determined. In each 10x10 m plot, all flowering plant species were enumerated. In addition, data on density, height and basal area of trees over 5 cm in diameter at breast height was estimated. The degree of forest or woodland cover was recorded on a five-point scale for three life forms i.e. trees, shrubs and herbs. The Daubenmire Cover Scale: 1:0-20%, 2:21-40%, 3:41-60%, 4:61-80% and 5:81-100% was used for determination of species population densities and frequencies. Species uniqueness (endemism, rarity, threat i.e. vulnerable, endangered) was analysed through literature review, voucher specimens and databases at the EA Herbarium. Plant species diversity for the first five plant community types was analysed using Shannon's Diversity Index (H'=Σ Pi Ln Pi). Species Evenness analysed using Shannon's Evenness Index (E=H' / H Max).

Overall, 186 different species of plants were recorded in Menengai Caldera with a vegetation cover density range of between 15% and 65%. The caldera floor is classified into 8 plant communities. There were no endemic, rare or new plant species recorded in this study, though certain tree species like *Rubus steudueri* and *Rubus apetalus* are recognized Montane forest species which were recorded in Madrugada farm. This suggests that conservation of these areas is vital. In this regard, efforts are required to conserve the forest and mitigate potential impacts from the ongoing geothermal exploration project in Menengai caldera.

1. INTRODUCTION

Forest ecosystems provide a continuous flow of goods and services that support the Kenyan economy directly or indirectly by sustaining livelihoods. Although forests cover only a small area of about 1.7% of Kenya's total land area (Toroitich, 2009), closed forests are crucial water catchments, and harbour a disproportionate amount of Kenya's biodiversity. Among these forests are the five largest blocks (also

referred to as "Kenya's water towers"), namely Mt. Kenya, Aberdares, Mt. Elgon, Cherangani and Mau Forest Complex, that has a combined area of 403,000 hectares. Menengai forest located in East Mau forms the northern boundary of Lake Nakuru and has resources that serve lots of benefits to the local communities in form of grazing, materials for construction, food fuel wood, and traditional medicine. However, there is no documentation of these. Further, although different forest resources are extracted from the forest continuously by local communities, the forest managers do not have information on how these resources influence socio-economic and the general wellbeing of those who depend on the forest.

The declining Menengai forest remains to be properly studied for flora and fauna and in particular, the key avifauna and invertebrate taxa, which support the ecosystem services such as pollination. Pollinators have a direct correlation to forest plant numbers, diversity (plant community composition) and population genetics (Calvo and Hortvitz, 1990) and they exert indirect effects on all higher trophic levels organisms that use plants for food or shelter (Abrams, 1995). Key habitat changes affect sensitive species, which may decline or disappear while still undocumented. The African pollinators Initiative, plan of action (Gemmill et al., 2003) highlights what needs to be done to conserve pollinators especially in agro-ecosystems and other habitats (Shepherd et al., 2003).

To guide current and future restoration interventions of the forest, it is important to know the types of flora and fauna and state of the resource users and the level of dependence on the relevant resources.

2. MATERIALS AND METHODS

2.1 Study site and Data Acquisition

Menengai (meaning "Mountain of God" in Maasai) lies north of Lake Nakuru and forms the northern divide of the lakes' catchment basin. It rises to a height of 2,278 masl and is the remnant of a volcano that erupted about 200,000 years ago (Leat, 1984). It is considered a dormant volcano, which is a volcano that has erupted in documented history. The last eruption occurred around 1,400 years ago (Leat, 1984).

Following the eruption, the sides of the volcanic crater collapsed inwards forming a large, gaping hole in the crust, called a caldera. Menengai caldera with an area of 90km^2 and a diameter of 12km is the second largest caldera in Africa after Ngorongoro in Tanzania. Menengai caldera is located in larger Nakuru District at 35^0 28', $35^0$36'E, and 0^o13', $1^0$10'S, and is one of the eighteen larger districts of the Rift Valley Province. The larger Nakuru district has recently been subdivided administratively, placing a large section of Menengai caldera in the Rongai and Nakuru north districts.

Rainfall recorded for the last 35 years (1976 – 2010) at Menengai caldera, Madrugada Farm -LR 6886/6, co-ordinate 36.0226^{o}E, 0.2535^{o}S, which is outside (600 m) from Menengai edge indicate that the annual rainfall ranges from 500-1500mm per annum with an annual mean rainfall of 923 mm and is not significantly different from the district annual mean of 988mm (Figure 1). The long-rain season is mainly in April to June while the short-rains season is in October/November. The rainfall shows a declining trend that may be attributed to the destruction of the forest cover. December to March is usually the dry season and the strong winds in the caldera precipitate frequent fire outbreaks. Temperatures range from 25°C-30°C.

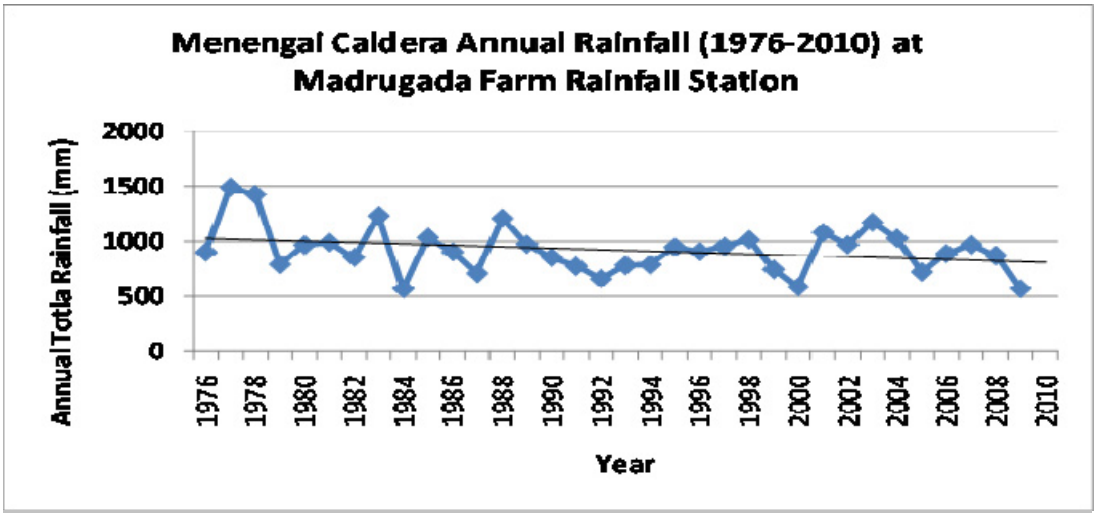

FIGURE 1: 1976 – 2010 Rainfall Madrugada farm, near Menengai caldera's edge (FOMEC, 2010)

Plant surveys were aimed at documenting the diversity of flowering plants in the Menengai Caldera forest system. Plant sampling sites were located at the Wanyororo B borehole drill sites, Central fumaroles, Southwest of the caldera (Madrugada farm), and at two geothermal well pads as shown in Figure 2 (see black circles).

Line transects were established in each forest type and used as baseline upon which sampling plots were located. Plots of 20x20 m were placed at intervals of 50 m and marked along the transect and used to quantify species distribution patterns and vegetation dominance (Mutangah, et al., 1997; KIFCON, 1993). Each block was divided into 4 (10x10 m) small plots within which vegetation parameters were determined. In each 10x10 m plot all flowering plant species were enumerated. In addition, data on density, height and basal area of trees over 5 cm in diameter at breast height (DBH) was estimated. The degree of forest or woodland cover was recorded on a five-point scale for three life forms i.e. trees, shrubs and herbs. The Daubenmire Cover Scale: 1:0-20%, 2:21-40%, 3:41-60%, 4:61-80% and 5:81-100% was used (KIFCON, 1993). The method is suitable for quantitative vegetation analysis because it allows determination of species population densities and frequencies.

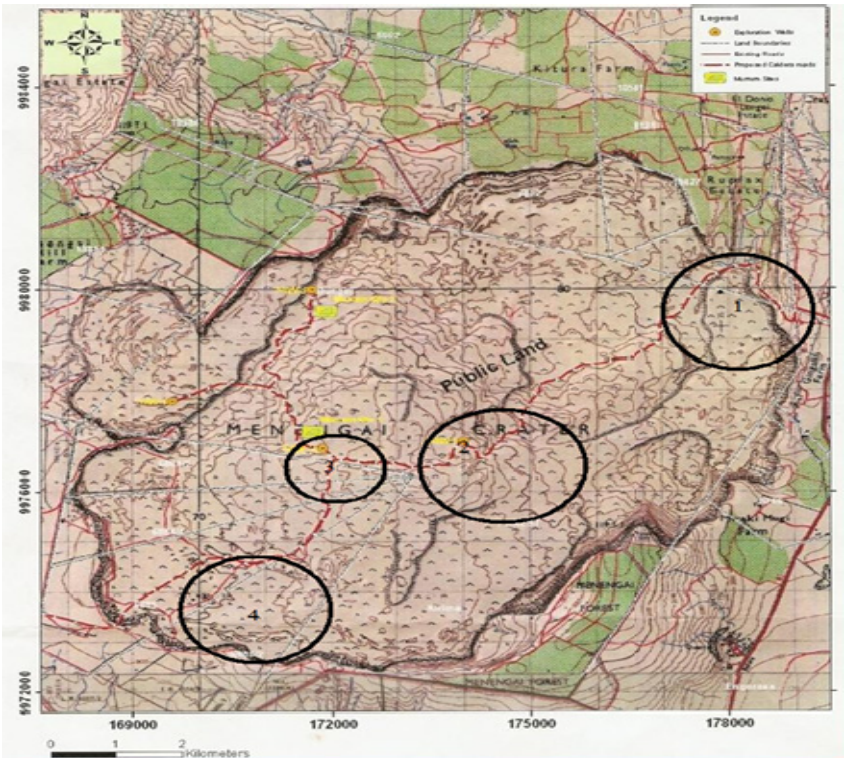

FIGURE 2: Study Area showing the plant sampling sites (modified from. KenGen. 2008)

General botanical surveys was also undertaken along each transect, within a band of 10 m on either side. These enabled a better understanding of the various habitat physiognomic structures. Mass plant collection and identification was undertaken with further verification done at East African herbarium. Plants that could not be identified *in situ* were identified at the East African Herbarium in Nairobi.

Floristic diversity was analysed using data on species richness (i.e. total number of species recorded per site) and comparison of floristic similarity between study sites. Forest structure was determined by analysing the canopy cover of different vegetation layers (herbs, climbers, shrubs and trees), diameter at breast height (dbh) and height data.

Species uniqueness (endemism, rarity, threat i.e. vulnerable, endangered) was analysed through literature review, voucher specimens and databases at the EA Herbarium. Species diversity for the different vegetation communities was computed using the modified inverse of Simpson-Yule diversity of concentration, C, for equally abundant species (Dunstan & Fox, 1996). Plant species diversity for the first five plant community types was analysed using Shannon's Diversity Index (H'=Σ Pi Ln Pi). Species Evenness analysed using Shannon's Evenness Index (E=H' / H Max).

2.2 Vegetation mapping methodology

Data was collected from various sources namely:

a) Kenya vegetation map (Map area: Nakuru District; Units: Metric Projection: UTM (Universal Transverse Mercator) Datum: WGS 1984.
b) Topographical map of Kenya at a scale of 1:50,000 covering Nakuru area (Topo Index 119-1)
c) Google Earth imagery

The initial map was developed by clipping the shapefile for the area covered by Nakuru in the vegetation map of Kenya in order to remain with the area under study. This was done in Arc GIS 9.30 software by extracting and Clipping using the Analysis Tool. The Clipped output shape file for Nakuru was later overlaid on top of the toposheet in order to add more details in the map.

Google Earth imagery was also used in the analysis. The study area was captured from Google Earth as a jpg-image and later on transferred into a GIS platform for further analysis. The image was geo-referenced and additional details for the vegetation shape files obtained through digitizing.
The layers from the analysis process; administration shape file and vegetation shape file, were combined in ArcMap to come up with the final map showing the vegetation distribution in the study area.

3. RESULTS AND DISCUSSION

The vegetation map of the study area was prepared. It shows that whole area is covered by vegetation and the cover density ranges between 15% and 65% (Table 1).

The vegetation was differentiated into 8 vegetation types namely: Bushlands (23%), Grasslands (21%), Forests (18%), Disturbed land (14%), Woodlands (10%), Rocky outcrops and lava vegetation (9%), Montane forest (3%) and riverine vegetation (2%). The vegetation cover density map of the area is shown in Figure 3.

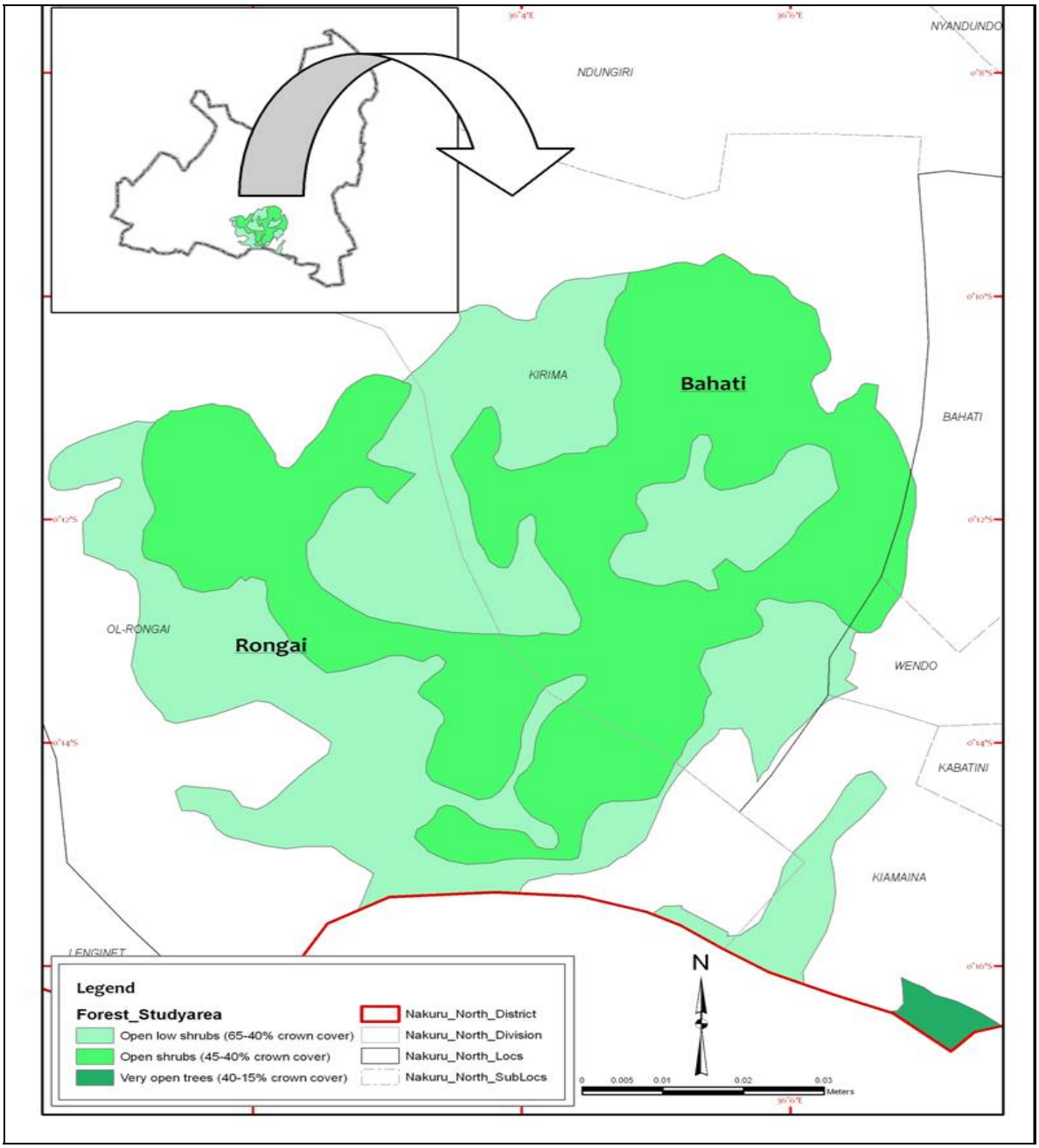

FIGURE 3: Vegetation distribution map of Menengai Caldera

TABLE 1: Plant species diversity and distribution

	Plant communities types				
	1	**II**	**III**	**IV**	**V**
Species diversity	2.48	3.41	1.57	3.24	2.69
Species evenness	0.65	0.78	0.59	0.89	0.69
Species richness	0.46	0.76	0.14	0.42	0.49

The natural vegetation in the caldera and its density, composition, and differentiation are directly related to the climate and economy of the area. The study of plant species and communities as a natural resource is of great importance. A record of 169 species of flowering plants and 17 species of grasses have been recorded in the caldera during this study (Table 2a and 2b).

TABLE 2a: Checklist of plant species recorded at the Madrugada Farm section (SW of caldera) during the entire study (June 2009-July 2010) and their biogeographical affinities

Family	**Genus**	**Species**	**Biogeographic affinities**
Malvaceae	*Abutilon*	*hirtum*	Riverine
Mimosaceae	*Acacia*	*abyssinica*	Acacia woodland
Mimosaceae	*Acacia*	*hockii*	Wooded grassland
Ericaceae	*Agauria*	*salicifolia*	
	Argyrolobium	*fischeri*	Wooded grassland
Compositae	*Berkheya*	*spekeana*	Grassland
	Chamaecrista	*falcinella*	Wooded grassland
	Chenopodium	*opulifolium*	Wooded grassland
Compositae	*Conyza*	*bonarrensis*	Weed in Arable Cultivation
	Conyza	*schimperi*	Wooded grassland
	Conyza	*stricta*	Wooded grassland
	Crotalaria	*lachnocarpoides*	Wooded grassland
Euphorbiaceae	*Croton*	*macrostachyus*	Forest & wooded grassland
	Cyathula	*cylindrica*	Wooded grassland
	Cynoglossum	*coeruleum*	Wooded grassland
Compositae	*Echinops*	*amplexicaulis*	Wooded grassland
	Erica	*arborea*	Wooded grassland
Euphorbiaceae	*Erythrococca*	*bongensis*	Open woodland & grassland
Proteaceae	*Faurea*	*saligna*	Wooded grassland
	Ferula	*communis*	Wooded grassland
	Helichrysum	*forskahlii*	Wooded grassland
	Helichrysum	*odoratissimum*	Wooded grassland
Umbeliferae	*Heteromorpha*	*trifoliate*	Bushland
	Heteropogon	*contortus*	Wooded grassland
	Hibiscus	*lunariifolius*	Wooded grassland
Lobeliasceae	*Lobelia*	*fervens*	Grassland
	Lobelia	*holstii*	Wooded grassland
	Lotus	*bequetii*	Wooded grassland
	Melinis	*repens*	Wooded grassland
	Micromeria	*imbricate*	Wooded grassland
Geraniaceae	*Monsonia*	*angustifolia*	Open woodland & grassland
Loganiaceae	*Nuxia*	*congesta*	
Rubiaceae	*Oldenlandia*	*monanthos*	Mountain grassland
	Polygala	*sphenoptera*	Wooded grassland
Proteaceae	*Protea*	*gaguedi*	Grassland
Rosaceae	*Rubus*	*steudneri*	Mountain forest & upland bushland
Rosaceae	*Rubus*	*apetalus*	Mountain forest & upland bushland
	Senecio	*mesogrammoides*	Wooded grassland
	Senecio	*ruwenzoriensis*	Wooded grassland
Solanaceae	*Solanum*	*mauense*	Forest margins
Solanaceae	*Solanum*	*mauritianum*	Wasteland
	Sopubia	*ramosa*	Wooded grassland

Family	Genus	Species	Biogeographic affinities
Labiatae	*Tetradenia*	*riparia*	Bushland
	Themeda	*triandra*	Wooded grassland
	Vernonia	*galamensis*	Wooded grassland
	Wahlenbergia	*abyssinica*	Wooded grassland
	Wahlenbergia	*virgata*	Wooded grassland
	Zornia	*setosa*	Wooded grassland
	Total	**48**	

TABLE 2b: Checklist of plant species recorded during the entire study and their biogeographical affinities. Plant species observed from June 2009-July 2010 at Wanyororo B pump station, (NE crater), the well pads (MW1, MW2, MW3 and MW4), campsite and along new road for geothermal thermal prospecting

Family	Genus	Species	Biogeographic affinities
Malvaceae	*Abutilon*	*mauritianum*	Riverine
Mimosaceae	*Acacia*	*tortilis*	Bushland
Mimosaceae	*Acacia*	*xanthophloea*	Woodland
Mimosaceae	*Acacia*	*lahai*	Woodland
Euphorbiaceae	*Acalypha*	*volkensii*	Upland grassland
Amaranthaceae	*Achyranthes*	*aspera*	Disturbed land
Compositae	*Ageratum*	*conyzoides*	Weed in disturbed ground
	Aloe	*lateritia*	
	Artemisia	*afra*	
	Arthropteris	*orientalis*	
Compositae	*Aspilia*	*mossambicensis*	Wild bushed grassland
Compositae	*Bidens*	*pilosa*	Variable common wasteland
Amaranthaceae	*Celosia*	*anthelmintica*	Dry bushland
	Chenopodium	*opulifolium*	
	Chlorophytum	*subpetiolatum*	
Verbenaceae	*Clerodendrum*	*myricoides*	Dry forest & bushland
Commelinaceae	*Commelina*	*bengalensis*	Bushland
Compositae	*Crassocephalum*	*montuosum*	Variable common wasteland
	Crotalaria	*brevidens*	
	Crotalaria	*laburnifolia*	
	Cucumis	*aculeate*	
Convolvulaceae	*Cuscuta*	*kilimanjari*	Forest
Araliaceae	*Cussonia*	*arborea*	Wooded grassland
Araliaceae	*Cussonia*	*holstii*	Bushed grassland
	Cyanotis	*foecunda*	
	Cycnium	*tubulosum*	
	Cyphostemma	*arundo*	
Solonaceae	*Datura*	*stramonium*	Disturbed land
Dioscoreaceae	*Dioscorea*	*quartiniana*	Bushland
Melastomataceae	*Dissotis*	*senegambiensis*	Grassland
Sapindaceae	*Dodonaea*	*viscosa var angustifolia*	Bushland in rocky lava sites
Dracaenaceae	*Dracena*	*steudneri*	Forest
	Dyschoriste	*radicans*	
Compositae	*Emilia*	*discifolia*	Stony area
	Erica	*arborea*	
	Eriosema	*jurionianum*	

Family	Genus	Species	Biogeographic affinities
Papilionaceae	*Erythrina*	*abyssinica*	Wooded grassland
Euphorbiaceae	*Euphorbia*	*candelabrum*	Rocky outcrops in bushland
Moraceae	*Ficus*	*glumosa*	Rocky outcrops & hillsides
Moraceae	*Ficus*	*ligens*	Rocky sites on lava
Moraceae	*Ficus*	*thonningii*	Forest & woodland
	Fuerstia	*africana*	
Compositae	*Galinsoga*	*parviflora*	Weed in moist highlands
	Geranium	*ocellatus*	
Urticareae	*Girardinia*	*diversifolia*	Wet disturbed land
	Gladiolus	*ukambensis*	
Papilionaceae	*Glycine*	*wightii*	Bushed grassland
	Gnidia	*involucrate*	
Tiliaceae	*Grewia*	*fallax*	Bushed grassland
Tiliaceae	*Grewici*	*similis*	Bushed grassland
	Guizotia	*scabra*	
	Gutenbergia	*cordifolia*	
	Helichrysum	*glumaceum*	
Rhamnaceae	*Helinus*	*integrifolius*	Bushland grassland
Labiatae	*Heonotis*	*nepetifolia*	Forest margin & Roadside
Malvaceae	*Hibiscus*	*cannabinus*	Dry grassland
Malvaceae	*Hibiscus*	*fuscus*	Grassland
	Hibiscus	*aethiopicus*	
	hildebrandtii	*Chamaecrista*	
	Hypoxis	*obtusa*	
	Impatiens	*sodenii*	
	Indigofera	*arrecta*	
	Indigofera	*spicata*	
Acanthaceae	*Justicia*	*calyculata*	Grassland weed
Compositae	*Kleinia*	*abyssinica*	Bushland
Verbenaceae	*Lantana*	*camara*	Weed in roadside &secondary vegetation
Verbenaceae	*Lantana*	*trifolia*	Bushed grassland
Verbenaceae	*Lippia*	*javanica*	Woodland
Celastraceae	*Maytenus*	*heterophyltus*	
Labiatae	*Ocimum*	*gratissimum*	Disturbed bushland
	Oldenlandia	*scopulorum*	
	Oldenlandia	*wiedemannii*	
Oleaceae	*Olea*	*europaea*	Dry forest & Woodland
Orobanchaceae	*Orobanche*	*minor*	Grassland & Forest edges
Oxalaceae	*Oxalis*	*corniculata*	Upland grassland
Anacardiaceae	*Ozoroa*	*insignis*	Wooded grassland
Graminae	*Panicum*	*maximum*	Grassland
	Pappea	*capensis*	*(Small tree)*
	Pavonia	*burchellii (P.patens)*	
Rubiaceae	*Pentas*	*longiflora*	Dry wooded grassland
Rubiaceae	*Pentas*	*lanceolata*	Forest edges
	Polygala	*erioptera*	
	Polygala	*petitiana*	
	Polygala	*sphenoptera*	

Family	Genus	Species	Biogeographic affinities
	Protea	*gaguedi*	
Compositae	*Psiadia*	*punctulata*	Bushed grassland
	Pteridium	*aquilinum*	
Vitaceae	*Rhoicissus*	*tridentate*	Wooded grassland
Anacardiaceae	*Rhus*	*natalensis*	Bushland
Anacardiaceae	*Rhus*	*vulgaris*	Wooded grassland
	Rhynchosia	*ferruginea*	
	Rhynchosia	*minima*	
Euphorbiaceae	*Ricinus*	*communis*	Dry woodland edges
Rubiaceae	*Rubia*	*cordifolia*	Bushed grassland
Poligonaceae	*Rumex*	*usambarensis*	Rocky bushed grassland
	Satyrium	*macrophyllum*	
	Scadoxus	*multiflorus*	
Oleaceae	*Schrebera*	*alata*	Forest & grassland
	Senecio	*ruwenzoriensis*	
	Senna	*didymobotrya*	
Caesalpiniaceae	*Senra*	*didymobotyra*	Forest edges
Malvaceae	*Sida*	*ovate*	Dry grassland
Solanaceae	*Solanum*	*incanum*	Variable common wasteland
	Solanum	*terminale*	
Umbeliferae	*Steganotaenia*	*araliacea*	Dry stony hillsides
Scrophulariaceae	*Striga*	*asiatica*	Grassland
	Striga	*linearifolia*	
Compositae	*Tagetes*	*minata*	Weed in upland arable land
Compositae	*Tarchonanthus*	*camphorates*	Bushed grassland
	Themeda	*triandra*	
Labiatae	*Tinnea*	*aethiopica*	Bushland & Wooded grassland
Tiliaceae	*Triumfetta*	*rhomboidea*	Pathsides and disturbed place
Urticareae	*Urtica*	*massaica*	Forest edges
Rubiaceae	*Vangueria*	*madaascariensis*	Rocky bushland
Compositae	*Vernonia*	*brachycalyx*	Dry forest edges
Compositae	*Vernonia*	*lasiopus*	Grassland
	Vernonia	*gallamensis*	
Solanaceae	*Withania*	*somnifera*	Woodland
Cucurbitaceae	*Zehnesia*	*scabra*	Sand forest, Bushland
	Zornia	*setosa*	
Total	**121**		

Results show that the caldera floor is classified into eight plant communities. Plants species with the highest cover/abundance scale was used to name the community type. Bushed grasslands dominated the vegetation and comprised of *Tarconanthus camphorates* (leleshwa)*, Euphorbia canderabra, Acacia repanolobium Rhus natalensis, Grewici similes, Acacia tortilis, Cussonia arborea, Kleinia abyssinica,* and mixed bushland comprising of *Commelina bengalensis, Aspilia mossambicensis, Tinnea aethiopica, Justicia calyculata, Rhoicissus tridentate, Oxalis corniculata, Rhus vulgaris, Ozoroa insignis, Erythrinaabyssinica Celosia anthelmintica, Pentas longiflora, Dioscorea quartiniana, Heteromorpha trifoliate, Tetradenia riparia, Faurea saligna, Echinops amplexicaulis.*

Open grasslands are composed of various associations of *Chloris gayana, Digitaria abyssinica, Sporobolus sp, Hyparhenia, Fibristylis exilis (geothermal grass), Cynodon nlemfuensis, Cynodon dactylon,* and *Boma Rhode* grasses. Plants recorded in open grasslands include *Lantana trifolia, Tarchonanthus camphorates, Panicum maximum, Grewia fallax, Striga asiatica, Sida ovata, Rubia cordifolia, Helinus integrifolius, Cussonia holstii, Psiadia punctulata, Vernonia lasiopus, Acalypha volkensii, Dissotis senegambiensis, Hibiscus cannabinus, Hibiscus fuscus, Glycine wightii, Protea gaguedi, Lobelia fervens* and *Berkheya spekeana.*

The forest species include *Urtica massaica, Zehnesia scabra, Dracena steudneri, Senra didymobotyra, Ficus thonningii, Orobanche minor, Olea europaea, Pentas lanceolata, Cuscuta kilimanjari, Croton macrostachyus, Erythrococca bongensis, Solanum mauense, Monsonia angustifolia, Nuxia congesta, Agauria salicifolia, Acacia abyssinica* and *Acacia hockii.*

Orchidaceae, commonly referred to as the Orchid family, is a morphologically diverse and widespread family of monocots. The taxonomy of this family is in constant flux, as new studies continue to identify more classificatory elements. The Orchidaceae is currently placed in the order Asparagales by the APG III system of 2009. A majority of orchids are perennial epiphytes, which grow anchored to trees or shrubs. Other species are lithophytes, growing on rocks or very rocky soil. One orchid genus, Vanilla, is commercially important, used as a flavouring. The scent of orchids is frequently analysed by perfumists (using Gas-liquid chromatography) to identify potential fragrance chemicals. The other important use of orchids is their cultivation for the enjoyment of the flowers.

Results of the vegetation study in the show presence of 14 orchids. These include *Polystachya transvalansis* (yellow flowers), *Ansallia Africana* (spotted orchid), *Ranyaeris amaniansis* (tree orchid), *Brachyconyttis pubancans*.

Two ground orchids namely, *Satyrium cheirophorum* Rolfe (pink flowers and leaves) and *Pteroglossapis ruwenzoriensis* (Rendle) Rolfe (white flowers with violet centre "lip") have been described as rather unusual. Other orchid species include; *Foxglora spp.*, *Cremastill spp.*, *Gladioli spp.*, *Eurochila spp.*, *Tessolatta spp.*, *Straga spp.*, *Gollingansis simplex*, and *chamnangis spp.* (tree orchid).

4. CONCLUSION AND RECOMMENDATION

For any geothermal project, land is required for drill pads, access roads, steam lines, power plant and transmission lines. During such development, soil in these areas may compacted and changed hence impacts on vegetation may include loss of indigenous species and species diversity; increased risk of invasive species; increased risk of topsoil erosion and seed bank depletion; increased risk of fire; and alteration of water and seed dispersal. This study which is a baseline recommends for regular vegetation mapping and monitoring during implementation of Menengai Geothermal drilling project.

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