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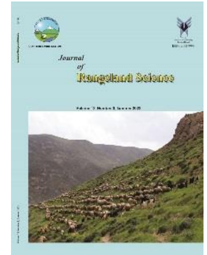

Research and Full Length Article:

Impacts of Gold Mining Activities on Vegetation Cover and Carrying Capacity (Case Study: Butana Rangeland, Al-Sobag Locality - Gadarif State, Sudan)

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Abstract. This study was conducted at Butana locality, Gadarif State-Sudan in October 2018. The study aimed to assess the impacts of gold mining on natural rangeland. Two range sites were selected in the study area (Site A) that affected by gold mining activities and the other one (Site B) was not affected in the same zone. Each site was divided into four plots. The plot location randomly selected to represent the area of gold mining activities. Four line transects were established at each range site. At each transects, two transects of length 100m distributed systematically, and four quadrates of size 1×1 m placed with an interval of 25m. Data were analyzed for vegetation attributes; organized, tabulated, and analyzed using standard range measurements equations. All data statistically analyzed (ANOVA) and mean comparisons were made using the Duncan procedure, SAS statistical program. The study found that there were significant differences between percentages of ground cover in terms of bare soil, rocks, litter and plant cover in the location close to the mining activities, there were an increased in the proportion of bare soil (56.37%) compared to the plant cover (2.25%). While there were no significant differences between the components of ground cover in the range site which was far from the mining area. Also, there were no significant differences in average biomass productivity for two areas (A & B), the range site near mining activity (A) produced about (13.16 g/m²) compared to the other range site which was located far-off from the mining activity (B) produced about (11.41 g/m²). The carrying capacity in the affected site (A) reaches about 0.026 Au/ha/year, compare to another site (B) 0.022 Au/ha/year. It was concluded that there are negative effects of traditional mining on the Al-Sobag rangeland, through increased bare soil, decreased ground coverage and productivity.

Key words: Transect**,** Bare soil, Vegetation cover, Biomass, Carrying capacity

Introduction

Rangelands play a major role in supplying the human population with animal products in the entire land region in the world, (Holechek *et al*., 2004). Rangelands exposed several problems negatively affected the natural resources in terms of vegetation composition, quantity and quality of fodder, (Abdelsalam and Elsaer, 2017). Over the last three decades, this cover has been affected by successive periods of drought and desertification, agricultural rain fed expansion, overgrazing, seasonal fires, unregulated expansion of water resources and exploitation and mining leading to sand creep southward into the savannah, (Anonymous, 2015). Rangeland degradation, a worldwide problem, loss of perennial grass cover and increase in annuals, unpalatable forbs and bush cover, **(**Musa *et al.,* 2016**).** Artisanal small-scale gold mining (ASGM), both at present and in the past, has had a major impact on soils and ecosystems; it causes complete deforestation, loss of biodiversity and soil degradation, (Grimaldi *et al.*, 2015). Gold surface mining intensely affected land use systems, caused in the widespread loss of ecosystem services and environmental degradation, (Schueler *et al*., 2011).According to Fayiah et al (2020) the combination mining activities with other factors such as overgrazing, the change of land use, climate change and tourism, have caused the degradation of grasslands. The gold mining is a good source of economic income, the misuse in the process conducted can be damaging to the environment, surface and ground water resources and health of the untrained miners and communities. During the rainy seasons, this polluted water contaminates fresh water sources, mainly rivers and underground sources. Moreover, destruction of fertile graze lands, where disorganized digging is operated, can be devastating for the fragile agricultural environment. Artisanal mining is associated with a number of environmental impacts, which are deforestation and land degradation, open pits which pose animal traps and health hazards, and mercury pollution, dust and noise pollution, (Yaw, 2011).

According to Meaza *et al.* (2017) the intensive gold mining activities modified vegetation status, structure and composition. Significantly, the number of individuals and frequency of woody species encountered were affected in the mining areas. Butana area in Gedarif State is among the most affected areas by the traditional mining process that practices by people are widespread in vast areas, and the domination of rain fed mechanized agricultural scheme. Artisanal gold Mining activities beginning in Batana area since 2010 and some minerals were discovered by the efforts of local community. Artisanal gold Mining activities were spread in many areas particular in Wad Bishara, Al-Khouili and other areas. About «250» thousands of local people work in gold mining exploration in Butana areas, in addition to that more than «26» companies are working in the gold mining exploration in same field, where Butana represented one of the most organized areas of mining exploration at the level of Sudan. The major impacts on grazing areas where the wells and pits were widely spread, which disturbed those interested in grazing and the environment, (Mohammed, 2020). These activities lead to changes in vegetation cover, soil degradation, and deterioration of the rangeland environment particularly in Al-Sobag areas.

According to Mohammed *et al*. (2020), Al-Sobag rangelands were negatively affected by the mining activity, which was reflected in the deterioration of vegetation cover and soil Moreover, the lack of information's and document about the impacts of the mining process on rangeland degradation and socio- economic problem that faces the pastoralists. This study aimed to assess the impacts of gold mining activities on natural rangeland vegetation cover, biomass productivity and rangeland carrying capacity of Al-Sobag area.

Materials and methods

Study area

This study was carried out at Butana locality, Al-Sobag area, Gedarif State, Sudan (Fig. 1). Geographically, Butana is located between latitude 13-16˚ N and longitude 34-37˚ E, with an area of about 34000 km². It lies within semi-arid zone where the annual precipitation ranges between 150-400 mm from north to south, (Elhadary, 2014). The maximum of the region temperature reach aboute 37 ℃ in summar and 22 ℃ in winter, (Yagoub *et al*. 2015). There are three main types of the natural vegetation in the Butana. Acacia trees are forming the major perennial type, including *Acacia tertilus*, *Acacia seyal* and *Acacia mellifera*. The shrubs are the second perennial type of vegetation in the study area, including bushy grasses scattered all over the region. The third type includes the annual grasses and herbs. Grasses include *Schoenefeldia gracilis* (Gabash), *Sorghum purpureosericeum* (Adar), while herbs include *Ipemea cardiosepala* (Hantut), *Ipomea cordofana* (Taber) and *Blepharis edulis* (Siha), (Mohammed, 2020).

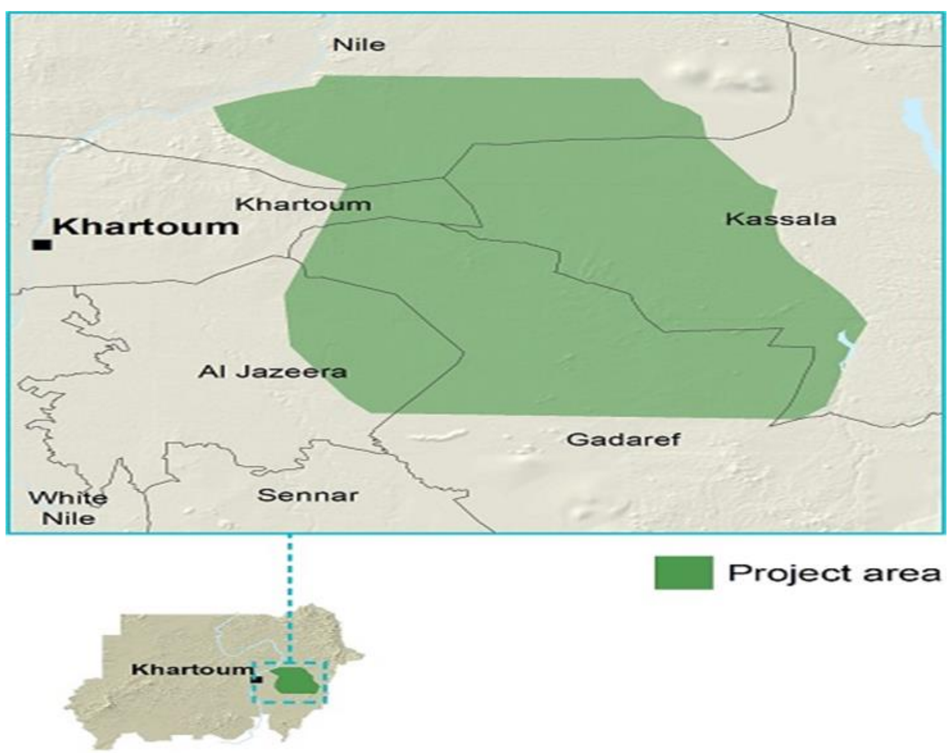

Fig. 1. Butana Area Map, Source: https://www.ifad.org - Butana Integrated Rural Development Project

Research method

Study concept

The concept of the study was to investigate the negative impacts of gold mining activities on rangeland resources at Butana area focusing on rangeland vegetation attributes and range carrying capacity.

Sampling procedures

Several initial visits were done to the study area to determine the range areas affected by the traditional mining activities in the rangelands of Butana area. Based on these reconnaissance surveys, Al-Sobag area was chosen as a range site representing these rangelands. Two range sites were selected in the study area (Side A) that affected by gold mining activities and the other one (Side B) did not affected by mining in the same zone.Each site was divided into four plots. The selections of plot location were randomly selected to represent the area of mining activities. Four lines transects with an angles 90°, 180°, 270° and 360° were determined by using compass were established at each range site. At each line transect, two transects of length100m distributed systematically and four quadrates of size 1×1m^2 placed through each transect with interval 25m between them; and 100m between the two transects in each side.

Ground cover determination

Ground cover was generally expressed as a percentage, so that all ground cover components (bare soil, litters, rocks and plant species) add up to 100%. The ground cover was determined along each 100 m transect, where plant species and other ground cover components were recorded with 3/4-inch parker loop (Parker, 1951) hits resulting in 100 hits in each transect with interval of one meter. The readings were recorded on parker loop sheet. Measured observations along the transect line will were usually four types of observation which are plant species (spp.), dead plants or litter (L) bare soil and rocks.

Following formulas will be used:

Plants cover = $\frac{total\ hits\ of\ all\ plants\ speciece s}{total\ hits} \times \%100$

Percent of bare soil = $\frac{Totalhits\ of\ baresoil}{tatal\ hits} \times \%100$

Percent of plant litters = $\frac{Total\ hits\ of\ litter}{total\ hits} \times \%100$

Percent of rocks = $\frac{Totalhits\ of\ rocks}{total\ hits} \times \%100$

Biomass productivity

Biomass is a commonly measured vegetation attribute that refers to the weight of plant material within a given area. Clip and weight method (harvesting method) was used to determine biomass productivity, (Muir and McClaran, 1997). Plant material from each quadrate along all transects in each site, were harvested at a level of 2.5 cm, above ground level using scissors then put in labeled paper bags. Dry matter content was determined by drying the sample in an oven, at (105 °C, for 48 hours). The dry weight obtained using a digital balance. Productivity per hectare was calculated and estimated to determine herbaceous productivity, expressed as Ton/ha.

Carrying capacity determination

To determine range carrying capacity in the study area the available forage was estimated according to the proper used factor 0.5 (Stoddard *et al*, 1975). The Tropical Animal Unit (TAU) of weight 250 kg forage consumption was used, which was consumed about 2.7 tons dry matter/year. The following formula was used to calculate the carrying capacity

Carrying capacity = $\frac{Available\ forage}{TAU\ consumption}$. It expresses TAU/ha/year.

Data analysis

Vegetation attributes, data were organized tabulated and analyzed using standard range measurements equations. All data tested by statistical analysis (ANOVA) and comparisons were performed using the Duncan procedure. SAS statistical program used to compare differences in vegetation attribute in the two areas and the differences between the means were compared.

Results and discussion

Rangeland ground cover

Ground cover refers to bare soil, litters rocks and plant cover. The mean of plant cover, bare soil, rocks and litter in two sites is presented in Table 1. Result indicated that, there are significant differences between percentages of ground cover in terms of bare soil, rocks, litter and plant cover in the location close to the mining activities, there are increased in the proportion of bare soil (56.37%) compared to the plant cover (2.25%).While there are no significant differences between the components of ground cover in the range site which is far from the mining area. These results explained the negative impact of the traditional gold mining on natural rangeland in Al-Sobag area. The increase of bare soil percentage in rangeland is a sign of range condition degradation, and it indicated that there is vegetation retrogression in these rangelands. According to Tafangenyasha, *et al.* (2011), the degraded area of rangeland characterized by low vegetation over, low litter and high percentage of bare soil. In that manner Fashir *et al*., (2012), stated that the bare soil, increase in the grazed compares with the un-grazed area. The high bare soil percentage in the unaffected area may be as a result of increased livestock numbers which were led to rangeland degradation and vegetation cover retrogression. This result agreed with Abdelsalam *et al*., (2017) who stated that open grazing system which was practiced in Sudan rangelands had a negative impact on vegetation cover and soil conservation. Sibanda *et al*, (2014) reported that the small scale mining affected negatively on grass species diversity and richness and change the type of vegetation. Also, there are indirect impacts of gold mining on the remotely area from mining area, because the herders avoid the affected area and concentrated their herds at unaffected range sites, which leads to overgrazing. According to Fashir *et al*., (2016) the plant cover is sensitive to the increase grazing pressure.

Table 1. The variation in average plant cover, bare soil, rocks and litter within two sites when parker loop method used

Areas	Bare soil	Rocks	Litter	Plant cover
Mined area (A)	56.37 a	16.12 a	20.87 b	2.25 b
Un mined area (B)	48.75 a	14.12 a	27.25 a	9.87 a

Means with the same letter are not significant different at Alpha: 0.05

Rangeland biomass production

There were no significant differences in average biomass productivity for two areas (A & B). These results indicated that the range sites in the study area were affected negatively by the mining activities near or far away from the mining drilling. The remote location of mining activity may be degraded due to the grazing animal concentration and intensive grazing pressure, which resulting decrease the rangeland area by increasing the traditional mining areas. Also the expansion of rain fed agriculture one of the most human activities affected in decreasing rangeland area. Papworth, *et al.* (2017), stated that the gold mining activities and agricultural businesses reduce tree cover. The range site near mining activity produced about 13.16 g/m² dry matter compared to the other range site which was located far away from the mining activity produced about 11.41 g/m². Therefore, productivity decreases in the remote area of mining due to the intensive use of this area by livestock as a result of the reduction of rangeland area. Elnour, (2001) reported that livestock grazing negatively affects the plants and the early livestock grazing consumes the plants in earlier stages before seed setting and tends to reduce the forage production. In general the rangeland in this area suffer by degradation and decrease the biomass productivity, as a result of negative human activities such as traditional mining practiced in the area, over grazing and animal concentration in range sites at a long time. Grazing removes the biomass above ground production if maintained at high intensity for sufficiently long period grazing can lead to loss of plant cover, shifts in species composition or volatilization loss of soil nutrients, (Steve and Chris, 2000). Yan *et al.* (2013) stated that the grazing has negative effects on grassland biomass and the grazing effect change with environmental conditions. Intensive and courteous grazing occur in this rangeland led to loss in biomass productivity and decreased the stocking rate. Abdelsalam *et al*. (2017) found that open grazing system affected negatively on range productivity and carrying capacity. Adam *et al.* (2015) reported that the population activities affect many plants species and absence of the others, and the change of plants condition makes the animals to prefer the palatable species in the area which affect the carrying capacity.

Table 2. Biomass Production

Source	FD	MS	F.value	Pr>F
Location	1	18.37	0.07	0.79 ns
Transect	3	611.81	2.29	0.11 ns
Quadrate	3	295.04	1.10	0.35 ns

ns= no significant differences at Alpha 0.05

Range productivity and carrying capacity

According to the results showed in Table 3 the carrying capacity of both range sites in Alsobag rangeland (A & B) affected negatively as a result of human misuse. The range carrying capacity near the mining area about 0.026 Au/ha/year, while the stock of unmind range site 0.022 Au/ha/year. This result explains the negative impacts of human activity on these range sites. The traditional gold mining activities led to decrease rangeland vegetation cover and loss of biomass productivity and finally led to decrease range carrying capacity and stocking rate. The decrease of rangeland area as a result of gold mining contributed in concentration of a large number of animals in specific range sites far from gold mining activities, which led to rangeland resources degradation and decrease the carrying capacity of these range sites. The gold mining in the range site, it may be increased the over grazing and intensive use of range resources by concentration of livestock in limited area contributed to rangeland ecosystem retrogression. This result agreed with Abdelsalam *et al*. (2017) who stated that open and intensive grazing of livestock had negative impacts on carrying capacity. The occurrence of human activities extensively in rangeland, especially gold mining and grazing, led to environmental degradation in this area, and negatively affected rangeland carrying capacity.

Table 3. Productivity and Carrying Capacity

Areas	Mean biomass (g/m^2)	Productivity (ton/ h/ year)	carrying capacity (TAU/h/Year)
Mined area (A)	13.16 a	0.07 a	0.026 a
Un mined area (B)	11.41 a	0.06 a	0.022 a

Means with the same letter are not significantly different at Alpha: 0.05

Conclusion

The increase of bare soil percentage, vegetation cover retrogression and decrease biomass productivity and range carrying capacity in the study range sites were main range condition indicators of the impact of traditional gold mining in these rangelands. The traditional gold mining activities led to decrease rangeland vegetation cover and loss of biomass productivity and finally led to decrease range carrying capacity. The misuses of rangeland of like traditional gold mining and over grazing may increase soil erosion and loosed upper layer of soil and attributed to decrease the live seed percentage. The implementation and integration of best practices for environmentally responsible extraction of gold from mining sites could also reduce the adverse effects of artesian gold mining on natural resources. Rehabilitation efforts are required to overcome the impacts of gold mining activities on sustainable rangeland management at Al-Sobag area in Butana.

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