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Modeling spatial distribution of goat grazing as a fuelbreak management tool in Mediterranean ecosystems

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Abstract. Forest fires occur frequently in Mount Carmel, Israel, as well as in other Mediterranean areas. Grazing is known to control wildfires by removal of flammable biomass. In order to optimize the use of grazing as a management tool in fire fuelbreak zones, land managers need to control grazing intensity and spatial distribution according to the given vegetation cover. Effective grazing is most likely to be applied by goat herds, which, as opposed to free-range beef cattle, are usually guided by a shepherd. However, assessing the stocking rates required to maintain effective fuelbreak zones is challenging due to the difficulties in evaluating herd spatial distribution and biomass removal. In an attempt to address this problem we monitored six goat herds using GPS collars, recording goat presence and activity (grazing, walking, and resting) for each area as well as the number of grazing days per area and stocking density. Effective grazing density was derived by modelling vegetation cover dynamics, i.e. the difference between annual biomass removal by grazing and primary production (g/m^2/year). This information may be used to determine the target number of grazing days to be sought by land managers for a given fuelbreak area. Quantifying grazing services for fire management in Mediterranean ecosystems can improve multi-purpose interfacing of pasture land and fuelbreaks.

Keywords. Goat grazing – Fuelbreaks – Mediterranean ecosystems – Grazing services – Modelling.

Modélisation de la distribution spatiale de chèvres sur parcours – un outil pour la gestion des zones de coupe feu dans les écosystèmes méditerranéens

Résumé. *Des feux de forêt surviennent fréquemment dans la région du Mont Carmel en Israël, de même que dans d'autres régions de la Méditerranée. On reconnaît que le pâturage aide à contrôler les incendies en réduisant la biomasse combustible. De façon à optimiser l'emploi du pâturage comme outil de gestion des zones de coupe feu, les gestionnaires de terrains doivent contrôler l'intensité et la distribution spatiale du pâturage en accord avec la végétation du terrain. Un service de pâturage adéquat est plus à même d'être fourni par des troupeaux caprins, qui, au contraire des bovins en pâturage libre, sont habituellement guidés par un berger. Cependant, l'évaluation du ratio requis pour le maintien de zones de coupe feu efficaces reste un défi, car il est difficile de mesurer la distribution spatiale des troupeaux, de même que la réduction de la biomasse. Nous avons tenté de traiter ce problème en contrôlant à l'aide de colliers GPS six troupeaux caprins, notant pour chaque aire la présence et l'activité des chèvres (pâturage, marche ou repos), de même que le nombre de jours de pâturage par aire et la densité du bétail. La densité de pâturage adéquate fut trouvée en modélisant les dynamiques de la végétation, plus précisément la différence entre la réduction annuelle de la biomasse par pâturage et la production primaire (g/m^2/année). Ces données peuvent être utilisées pour aider les gestionnaires de terrains à déterminer le nombre requis de jours de pâturage pour une zone de coupe feu. La quantification des services pastoraux pour la gestion des incendies dans les écosystèmes méditerranéens pourrait améliorer l'interfaçage multifonctionnel des zones pastorales et des zones de coupure de combustible.*

Mots-clés. *Pâturage caprin – Zones de coupe feu – Écosystèmes méditerranéens – Service de pâturage – Modélisation.*

I – Introduction

The Mediterranean Basin has been subject to various human disturbances such as grazing, clearing and prescribed fires for millennia (Naveh and Dan, 1973). Abandonment of traditional herding and agriculture in Mediterranean regions has led to changes in vegetation and land use patterns, consequently increasing wildfire hazard (Perevolotsky and Seligman, 1998). Furthermore, increasing development in exurban and rural areas into fire-prone ecosystems has increased the risk of fires at the wild land-urban interface. Due to an increase in wildfire frequency and severity in Mediterranean regions, during the 20th century (Pausas *et al*., 2008), the importance of active management of forest and scrubland interface is increasing.

Fuelbreaks are established as a part of proactive planning to reduce fire intensity, extent and progress, providing safer access for fire fighters (Omi, 1996). A fuelbreak is "a strategically located wide block or strip, on which a dense cover of flammable vegetation has been permanently changed to one of lower fuel volume and reduced flammability" (Green *et al*., 1977). This is achieved by removal of forest and woodland biomass by mechanical means, which requires costly investments. Due to the successional dynamics of Mediterranean ecosystems, herbaceous and woody vegetation in the fuelbreak area recover rapidly within a short period of time, and therefore require proper maintenance. Generating fuelbreaks in Israel was recommended after the 1989 Mount Carmel fire, but not implemented. The 2010 fire in the same region, claimed 44 lives, caused 17,000 people to be evacuated from their households, and burned nearly 25,000 acres. Subsequently, the need to establish fuelbreaks emerged again (Israel Ministry of Environmental Protection, 2011).

One economical and effective and economical means of maintaining fuelbreaks over time is the use of grazing. Goats exhibit a greater propensity to browse woody vegetation than cattle and sheep, and the mobility of goat herds is easily controlled by a shepherd. Thus, effective grazing for wildfire reduction management is most likely to be applied by goat herds. The benefits of goat grazing for biodiversity and its necessity as a fire hazard management tool are increasingly realized. The main challenge of using goat herds for fuelbreak maintenance in Mount Carmel is that goats are scarce and their spatial distribution is largely unknown.

Our research goals were: (i) to quantify spatial grazing pressure; and (ii) to develop quantitative tools of spatial modeling to determine the duration and intensity of grazing needed for the maintenance of fuelbreaks.

II – Materials and methods

Study area. The Carmel Heights, south of Haifa, Israel, run parallel to the Mediterranean Sea shore and peak at 546 m a.s.l. It covers an area of 250 km^2 (25,000 ha), characterized by Mediterranean climate, with dry summer and cool, wet winter, with an average annual precipitation of 600 mm. The study area is heterogeneous in vegetation types, with natural Mediterranean forest, woodland and scrubland combined with planted Aleppo pine forests (Zohary, 1960).

Grazing monitoring. We monitored the daily grazing routes of 11 herds using GPS. The GPS unit (i-gotU GT-600, Mobile Action Technology Inc., Taiwan) was placed on one individual goat per herd, using a customized collar. The location data was recorded at a high frequency (every 10 seconds) and locations were imported into a geographic information system (GIS). The data enabled calculation of goat presence and activity (grazing, walking, and resting) for each area seasonally and annually. These data were used to calculate the grazing pressure and effective grazing density.

GPS collar representation of a herd in space. The instantaneous spatial distribution of a goat herd depends on vegetation structure and landscape terrain. In order to calculate how a GPS collar represents a herd in space, a preliminary experiment was conducted. The width of a goat herd was measured at the widest point of the herd, by using a laser rangefinder (i-gotU GT-600, Mobile Action Technology Inc., Taiwan) in different vegetation covers and terrains.

Calculating grazing pressure. Grazing pressure was calculated by creating a grid with 1-ha tiles, used for counting the number of GPS locations per cell and the total time that was spend by the flock:

$$\frac{\text{grazing pressure}}{\text{cell}} = \text{count}\left(\frac{\text{gps call}}{\text{cell}}\right) * \frac{1}{1\ \text{call frq}\ (\text{gps call/min})} * \frac{1(\text{grz\_day})}{60\left(\frac{\text{min}}{\text{hr}}\right) * 4\ (\text{hr})}$$

$$\frac{\text{grazing pressure}}{\text{cell}} = \frac{\text{grazing pressure}}{\text{cell}} = \frac{\text{count}}{240}\left(\frac{\text{grz\_day}}{\text{cell}}\right)$$

count: number of GPS calls/cell
Cell: 1 ha (100 m*100 m)
call frq: GPS sampling frequency (GPS call /min)
grz_day: grazing day = 4 grazing hours

III – Results and discussion

Grazing monitoring. Differences between seasonal pasture uses of a herd were revealed. These differences are probably caused by vegetation characteristics and height: open and shady in the summer as opposed to dense and low in the winter. In addition, spatial grazing patterns were compared to existing locations of fuelbreaks around settlements.

GPS collar representation of a herd in space. GPS collar representation of a herd was studied under different vegetation covers: open shrub land, thin shrub land, dense shrub land and walking trail. The herd representation was calculated to be a disk 20 m in diameter around the GPS collar location (Table 1).

Table 1. Calculating GPS collar representation of a herd

Vegetation type	Mean (m)	N	prop	prop*mean(m)
Open shrubland	29.96	60	0.189	5.671
Sparse shrubland	20.534	142	0.448	9.198
Dense shrubland	14.113	97	0.306	4.318
Walking trail	8.395	18	0.057	0.477
Total		317	1	19.66

Calculating grazing pressure. GPS fixes for a GIS grid cell (1 ha) and the total time that was spent by each herd were calculated seasonally (see example in Fig. 1). High herd presence was detected in some areas, which imply that fuelbreaks should be designed in accordance to existing grazing patterns. Additionally, grazing patterns can be manipulated by using incentives such as water facilities in order to adjust the grazing patterns of a herd to existing fuelbreaks. Manipulating grazing patterns must consider fuelbreak area and herd size, location of neighbor herds and distance from the herd's premises.

Effective grazing management could be derived by modeling vegetation cover dynamics, e.g. the difference between yearly biomass removed by grazing and primary production (g/m^2/year). This information may help determine the number of grazing days to be targeted by land managers for

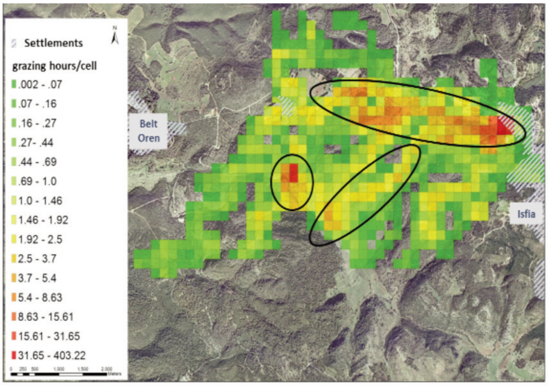

Fig. 1. Goat herd seasonal grazing hours/cell. Circled in black: hig herd presence calls.

a given fuelbreak area. Furthermore, this information could be used for examining different fuelbreak maintenance scenarios such as increasing herd size, adding pasture area, troughs, and subsidizing grazing, on a variety of timescales (Fig. 2).

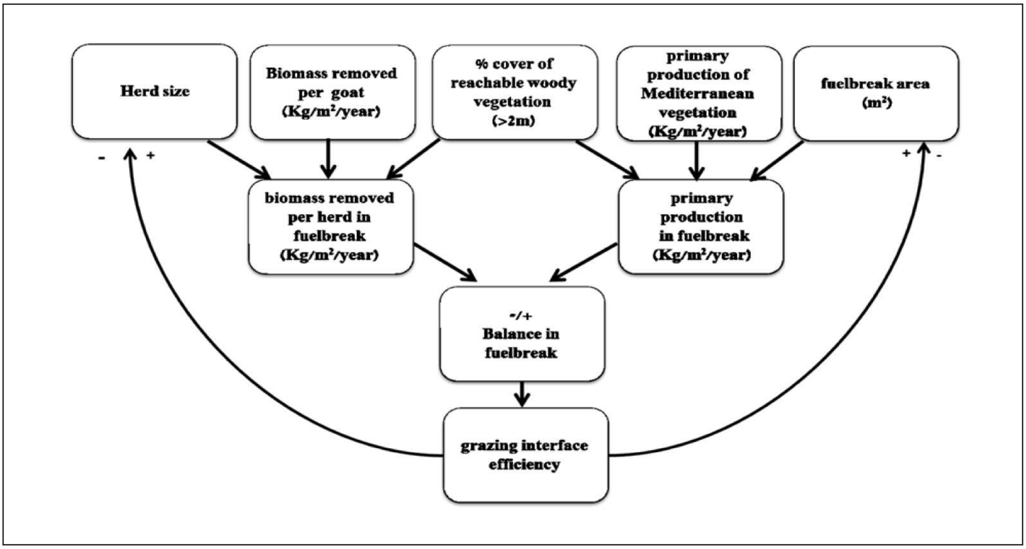

Fig. 2. Theoretical model for effective grazing management.

IV – Conclusions

This study presents an approach that could be used as a decision support tool for planning and maintenance of fuelbreaks by goat herds. GPS monitoring is contributory in quantifying grazing services that local herds can provide to maintain fuelbreaks. Fuelbreaks can be designed in accordance to existing grazing patterns or maintained by manipulating nearby goat herds, using incentives such as water availability. Linking spatial and socio-economic analysis can provide information about the means to preserve local extensive goat grazing by understanding the limiting factors for the presence and size of each herd. In a wide-range timescale there is a need to establish regulations for the continuity of extensive and traditional goat grazing. This study addresses Mount Carmel area but probably can be applied to other Mediterranean ecosystems as a multi-purpose interface of pasture land and fuelbreaks.

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