# Remote sensing for real time estimate of aboveground biomass productivity in mountain pasture

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# Remote sensing for real time estimate of aboveground biomass productivity in mountain pasture

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**Abstract.** Precision grazing may increase the farm business productivity, through improved pasture and animal management. One of the main issue is to estimate the real productivity of the pasture, in order to program the correct grazing load at each moment of the year. The aim of the study was to verify if the data acquired by the new European satellite system named “Sentinel 2” could be used for estimation of aboveground biomass in a mountain pasture. During 2016 growing season, in a Central Italy mountain pasture (M. Tilia, Rieti), we built nine grazing exclusion fences (12 m x 12 m), including the Sentinel 2 acquisition grid (10 m x 10 m pixel). Inside each plot, we cut grass (5 $m^2$) once a month for three months. The grass was weighed and analyzed for chemical and physical parameters. At the dates matching with cuts, free-of-charge red and infrared bands were acquired from Sentinel 2 data hub, in order to calculate NDVI (Normalized Difference Vegetation Index). In a GIS environment, we extract NDVI values for each plot. To explore how NDVI relate to biomass, linear regression analyses were performed. NDVI, varying from 0.41 to 0.83, showed strong linear relationships with green biomass ($R^2$ = 0.6356). A lower relationship was observed between NDVI and dried biomass ($R^2$ = 0.4678). The model, after being further refined, can be used to spatialise data over vast grazing areas, with high temporal frequency (5-10 days), helping in a more precise planning of livestock grazing.

**Keywords.** NDVI – Precision grazing – Grassland – Remote sensing.

***Remote sensing pour l’estimation en temps réel de la productivité de la biomasse aérienne dans les pâturages de montagne***

***Résumé.*** *Le pâturage de précision peut augmenter la productivité des entreprises agricoles, grâce à l’amélioration de la gestion des pâturages et des animaux. L’un des principaux problèmes est d’estimer la productivité réelle du pâturage, afin de programmer la charge des animaux correcte à chaque moment de l’année. Le but de l’étude était de vérifier si les données acquises par le nouveau système européen de satellites appelé “Sentinel 2” pouvaient être utilisées pour l’estimation de la biomasse aérienne dans un pâturage de montagne. Au cours de la saison de croissance 2016, dans un pâturage de montagne de l’Italie centrale (M. Tilia, Rieti), nous avons construit neuf clôtures d’exclusion de pâturage (12 m x 12 m), y compris la grille d’acquisition de Sentinel 2 (10 m x 10 m de pixel). À l’intérieur de chaque parcelle, nous coupons l’herbe (5 $m^2$) une fois par mois pendant trois mois. L’herbe a été pesée et analysée pour des paramètres chimiques et physiques. Aux dates correspondant aux coupures, les bandes rouges et infrarouges gratuites ont été acquises de Sentinel 2, afin de calculer le NDVI (Normalized Difference Vegetation Index). Avec un software SIG nous avons extrait les valeurs de NDVI pour chaque parcelle. Pour explorer comment NDVI se rapporte à la biomasse, des analyses de régression linéaire ont été. NDVI, variant de 0,41 à 0,83, a montré de fortes relations linéaires avec la biomasse verte ($R^2$ = 0,6356). Une relation inférieure a été observée entre le NDVI et la biomasse séchée ($R^2$ = 0,4678). Le modèle, après avoir été affiné, peut être utilisé pour spatialiser les données sur de vastes zones de pâturage, avec une fréquence temporelle élevée (5-10 jours), ce qui aide à une planification plus précise du pâturage.*

***Mots-clés.*** *NDVI – Pâturage de précision – Prairie – Remote sensing.*

## I – Introduction

Grasslands are one the most widespread vegetation types all over the World (Latham *et al*., 2014), playing a central role for ruminant nutrition in many countries. Permanent pastures play a key role in climate change (FAO, 2014), regulating the global carbon cycle (Franzluebbers, 2010) acting as carbon sink (Derner and Schuman, 2007), contributes to the maintenance of ecosystem services, including plant and animal biodiversity (Punjabi *et al*., 2013; Primi *et al*., 2015), hydrogeological stability and landscape conservation.

Erroneous livestock management practices, such overgrazing or undergrazing, may leads to grassland degradation, with the risk of losing these benefits. Having accurate and reliable data on the status of pastures is one of the needs for proper grazing load planning. Information concerning sward height, biomass, quality, phenological stage, productivity level, species composition are traditionally acquired with on-field measurement, with intensive efforts and with inappropriate method for large-scale coverage (Ali *et al*., 2016).

Modeling approaches joined with satellite remote sensing-based techniques permits large scale observation, quantification and prediction at varying temporal and spatial resolutions (Nordberg and Evertson, 2003), allowing a precision farming approach also for grazing livestock (Primi *et al*., 2015). Remote sensing-based studies have demonstrated the potential for grassland monitoring with different approaches, and increasing the spatial and temporal resolution seems to be the future challenge, as well as the communication of the benefits and opportunities to the farming community (Ali *et al*., 2016).

The aim of the study was to verify if the data acquired by the new European satellite system named "Sentinel 2" could be used for estimation of aboveground biomass in a mountain pasture, contributing to the scientific debate on the topic.

## II – Material and methods

### 1. Aboveground grassland productivity

The studies were conducted during the year 2016 growing season (June-September). In a Central Italy mountain pasture (M. Tilia, Rieti, 42°32'56.60''N, 12°32'56.60''E) (Figure 1), we built nine grazing exclusion fences (12 m x 12 m), including the Sentinel 2 acquisition grid (10 m x 10 m pixel). Inside each plot, we cut grass (5 $m^2$) once a month for three months. The grass was immediately weighed (fresh weight, FW). A quote was taken to the laboratory for chemical analysis.

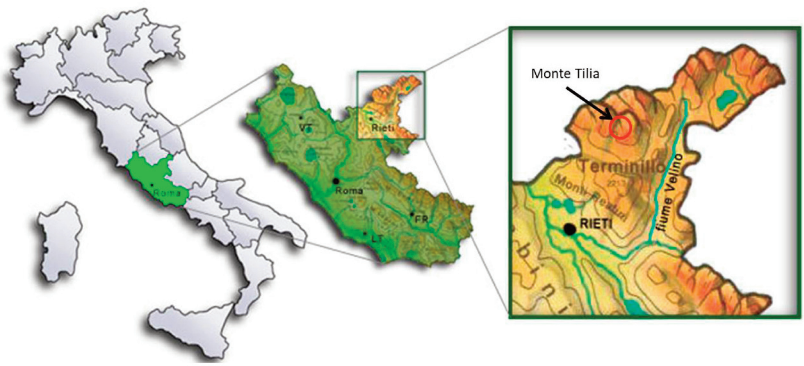


**Fig. 1. Study area.**

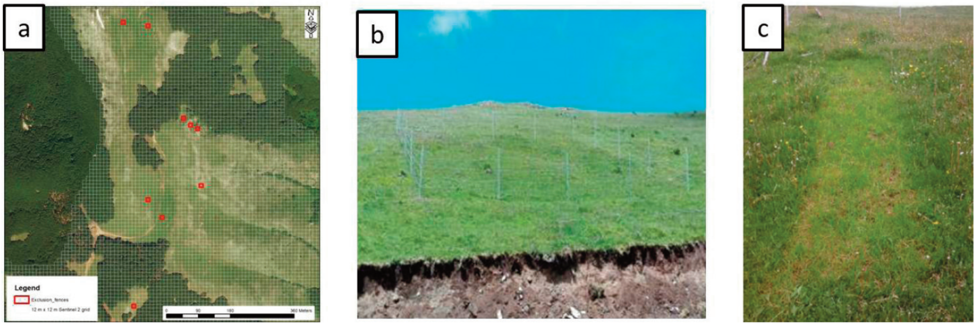


**Fig. 2. a) Localization of the 9 exclusion fences over the Sentinel 2 grid; b) example of esclusion fence; c) 5 m$^2$ grass cutting plot.**

## 2. Chemical analysis

The grass was analyzed for chemical parameters, such as dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF) and ash as reported by AOAC (2012) procedures (ID number: 2001.12, 978.04, 920.39, 978.10 and 930.05 for DM, CP, EE, CF and ash respectively). Neutral detergent fibre was assayed with a heat stable amylase and expressed exclusive of residual ash (aNDFom), acid detergent fibre expressed exclusive of residual ash (ADFom) and ash were determined according to AOAC methods 984.13 (A-D), 920.39, 2002.04, 973.18 and 942.05 (AOAC, 2012).

## 3. Statistics

NDVI was related to field measured biomass (t ha$^{-1}$) and to the chemical parameters using simple linear regressions. Statistics were performed with Statistica 10 software (StatSoft, Inc., 2011).

# III – Results and discussion

The summary statistics of biomass dataset are reported in Tab. 1. NDVI, varying from 0.41 to 0.83, showed a good linear relationships (Y=18.681X-7.1557, $R^2$=0.64, Standard Error of the Estimate [SEE]=1.59, P<0.001) with green biomass (Fig. 4). As expected, a lower relationship (Y=4.1051X-1.0457, $R^2$=0.47, SEE 0.49, P<0.001) was observed between NDVI and dried biomass.

**Table 3. Summary statistics of measured biomass for the data set**

| | Mean | Min | Max | Range | Std. Dev. | Coef. Var. |
|---|---|---|---|---|---|---|
| Fresh green biomass (t ha$^{-1}$) | 5.04 | 0.15 | 22.96 | 22.81 | 5.13 | 101.81 |
| Dry green biomass (t ha$^{-1}$) | 1.75 | 0.12 | 6.13 | 6.01 | 1.48 | 84.64 |

Significant correlation at P<0.05 was found between NDVI and ether extract (P=0.045) and NDVI and Acid Detergent Fibre (P=0.017), however with lower coefficient of correlation ($R^2$= 0.10 and 0.19, respectively).

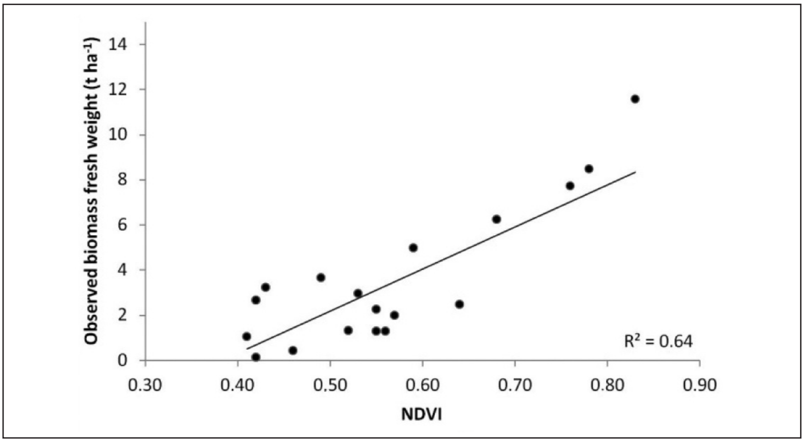


**Fig. 3. Linear regression model fitting observed biomass fresh weight *vs.* NDVI.**

## IV – Conclusions

The simple linear regression model, after being further refined and validated, can be used to spatialise data over vast grazing areas, with high temporal frequency (5-10 days as Sentinel 2 acquisition of images), helping in a more precise planning of livestock grazing. Other vegetation indexes (i.e. REP, SAVI, TSAVI) could be used in order to minimise inaccuracies (e.g., mitigating the effects of atmosphere and background reflectance etc.) or to find some possible relationship with chemical composition (i.e. with the nitrogen content).

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