Acta Scientiarum
http://www.uem.br/acta
ISSN printed: 1806-2636
ISSN on-line: 1807-8672
Doi: 10.4025/ actascianimsci.v39i4.35426

# Indicators of land use by cattle: associations among methods and role of environmental factors

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**ABSTRACT.** The objectives of this study were to investigate the associations among direct and indirect indicators of land use by cattle and to understand the role of some environmental factors on the definition of these indicators. The study was carried out in two areas, Nature Reserve (63.6 ha) and Private Area (30.4 ha), with 53 Hereford animals in each area. Daytime observations of animals' location were used as direct indicator of land use; while cattle track and dung pat distributions throughout the areas were used as indirect indicators. Environmental characteristics recorded were: terrain slope, prevalence of woody vegetation cover (forests, isolated tress and open grasslands), as well as the position of fences, water sources and salt blocks. Spatial correlations among the three indicators of land use were low ($r$ < 0.30). The environmental factors had lower predictive power of animals' sightings distribution, followed by cattle tracks, and the highest predictive power occurred for dung pat distribution. We concluded that each one of the methods evaluated in this study addresses a different aspect of land use by cattle. The environmental factors assessed were useful to predict the dung pat distribution, but less valuable to predict the cattle tracks and animals' sightings distributions.

**Keywords:** beef cattle, tracks, dung pats, spatial statistical analysis, geographic information system.

## Indicadores de uso do espaço por bovinos: associação entre métodos e o papel de fatores ambientais

**RESUMO.** Este estudo foi realizado para investigar as associações entre indicadores diretos e indiretos do uso do espaço por bovinos, além de avaliar o papel de algumas características ambientais na definição desses indicadores. O estudo foi conduzido em duas áreas, denominadas Nature Reserve (63,6 ha) e Private Area (30,4 ha), com 53 bovinos da raça Hereford em cada área. Observações comportamentais foram utilizadas como indicador direto do uso do espaço, enquanto as distribuições de trilhas feitas pelo gado e de placas de fezes foram utilizadas como indicadores indiretos. As características ambientais avaliadas foram: declividade, tipo de cobertura vegetal (florestas, pastagem com árvores isoladas, áreas abertas de pastagem), posição de cercas, fontes de água e sal. As correlações espaciais entre os três indicadores de uso do espaço foram baixas ($r$ < 0,30). As características do ambiente tiveram baixo poder de predição da distribuição espacial dos animais, seguido pela distribuição das trilhas e maior para as placas de fezes. Concluímos que cada um dos métodos avaliados aborda um aspecto diferente do uso do espaço pelos bovinos. As características ambientais avaliadas foram úteis para predizer apenas a distribuição das placas de fezes, sendo menos úteis no caso das trilhas e observações diretas dos animais.

**Palavras-chave:** bovinos de corte, trilhas, placas de fezes, análise estatística espacial, sistema de informação geográfico.

## Introduction

The expansion of livestock production areas and the resulting occupation of natural and semi-natural areas have raised local concerns about the conservation of these ecosystems (Carvalho & Batello, 2009; Zamorano-Elgueta et al., 2014), even though the impact of livestock on those environments has been shown to be complex.

For example, it is usually expected that cattle presence in natural areas increases the risk of soil erosion, water pollution and loss of biodiversity (Carvalho & Batello, 2009; Hirata et al., 2009; Zamorano-Elgueta et al., 2014). However, livestock grazing may also have positive effects on natural and semi-natural grasslands, being beneficial for plant species richness (Putfarken, Dengler, Lehmann, &

Härdtle, 2008) and reducing the risk of wildfires (Davies, Boyd, Bates, & Hulet, 2015). Therefore, a thorough assessment of livestock land use patterns is critical for developing optimal management strategies and ensuring sustainability of cattle production in natural and semi-natural areas.

The patterns of land use by cattle have been assessed mainly by direct observations, recording cattle spatial location by using visual sightings or GPS collars (Miguel, Rodriguez, & Gomez-Sal, 1997; Schlecht, Hülsebusch, Mahler, & Becker, 2004; Orr et al., 2012). These methods are usually representative of short-term land use, being limited to the periods of the day when the samplings are done (only during daylight in the case of visual sightings) or in terms of number of animals tracked (in the case of GPS collars). Another possibility to address the land occupation by cattle would be the use of indirect methods, for example, the location of cattle tracks on the terrain (Ganskopp, Cruz, & Johnson, 2000; Tate, Dudley, McDougald, & George, 2004) and the distribution of dung pats over the pastures (Tate, Atwill, McDougald, & George, 2003; Hirata et al., 2009). Such indirect indicators gather representative data of long-term land use throughout days and nights, as well as for an unlimited number of individuals; however, seasonal variations in the patterns of land occupation may not be evident.

Given these differences among direct and indirect observational methods, it is important to know the extent to which the outcomes arising from these methods are associated, and how they can be influenced by characteristics of the environment, revealing if the predictive power of environmental factors on land use patterns depends on the indicator of land use employed. The objectives of this study were to investigate the associations among direct and indirect indicators of land use by cattle and to understand the role of some environmental factors on the definition of these indicators.

## Material and methods

The study was conducted in two areas located in the Västra Götaland County in Southwest Sweden. The first area (called Nature Reserve), with 63.6 ha, was a part of the Ranna Ryd Nature Reserve, located at latitude 58°25'33"N, longitude 13°50'29"E, with 42.87 ha of open grassland (67% of the total), grassland with trees and shrubs (8%) and forests (25%). The second area (called Private area), with 30.38 ha, was an area of pasture located in latitude 58°22'50"N, longitude 13°48'33"E, with 23.51 ha (71% of the area) covered by open grassland, 16.6 ha (23%) covered by grassland with trees and a small forest with 1.4 ha (6%) (Figure 1). The altitude of the areas ranged from 530 to 670 m above sea level, with slopes averaging 13.10 ± 14.52° and 10.17 ± 8.56° (mean ± SD) in Nature Reserve and Private Area, respectively. The climate was a temperate continental type (DFB), according to the Köppen classification.

The Nature Reserve open areas were mainly covered by native grass species and by many clover and herbs species. The open grasslands at Private Area were covered mainly by high-yielding grasses and clover species, with few herbs. In both areas, the grazing season starts in May and finishes in October, during the other periods of the year cattle are kept indoors.

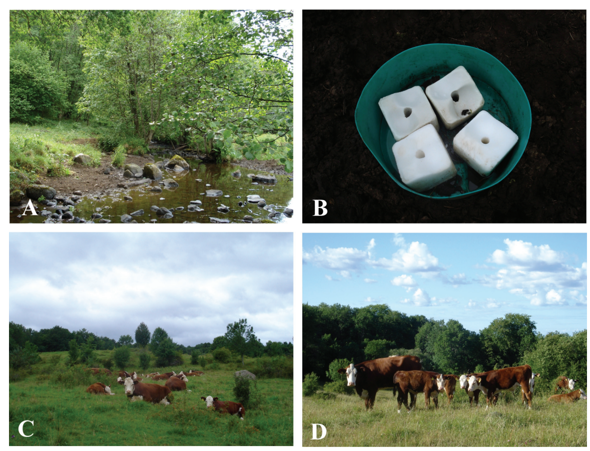


**Figure 1.** The two study areas, Nature Reserve and Private Area, located in Southwest Sweden, in September 2008. **A**. Water sources at the Private Area. **B**. Salt blocks offered in both pastures. **C**. Landscape of the Private Area, showing the studied cows and calves in an area of grassland with trees and shrubs. **D**. Landscape of the Nature Reserve, showing animals in an open grassland and a forest border in the background of the picture.

### Direct observation of cattle location as an indicator of land use

The direct observations were conducted on two lots of 53 Hereford cattle, each lot was located in one of the study areas, where the animals had continuous access to the whole terrains from May to October 2008. The lots were composed by one bull, 40 cows, and 12 suckling calves at Nature Reserve and of one bull, 37 cows and 15 calves at Private Area. The occupation density in the Nature Reserve was 0.87 animal $ha^{-1}$, and 1.74 animal $ha^{-1}$ in the Private Area. The animals had access to the available forage in the respective areas, receiving only mineral supplementation (mineral salt blocks) *ad libitum* and constantly available.

The method of fixed transects was used to record the location of animals in the study areas (Buckland, Anderson, Burnham, & Laake, 1993). Transects were walked by two observers, looking for the animals; one with 3,055 m on the Private Area and the other with 3,951 m on Nature Reserve. The routes were distributed all over the areas, enabling the observer to have a complete view of the pastures. When one or a group of animals was sighted, the observer went to the exact local where the animals were, recorded the geographical coordinates (WGS84) of their location using GPS handset (E-trex Vista HCx, Garmin International Inc., Olathe, KA), and then returned to the transect. Direct observations were carried out during three months (from July to October 2008), with 10 observations per month in each area, totaling in 30 sessions per area. The transect of each area was coursed once a day during daylight, alternating the observation time across the days, according to five predefined classes of time (from 8 to 10h, 10 to 12h, 12 to 14h, 14 to 16h and 16 to 18h). It was assumed that sites with a larger number of animals were those with higher occupancy rates.

### Indirect observations of behavior as indicators of land use

The layout of cattle tracks and the distribution of dung pats were used as indirect indicators of land use by cattle; whilst assuming that sites with greater concentration of dung pats and cattle tracks had higher occupancy rates. The recording of the location of cattle tracks and dung pats sampling were carried out once, in September 2008.

Tracks were defined as routes systematically used by cattle, whose constant movement caused changes in vegetation and soil, resulting in lines with clear exposure of the soil and presenting a concave surface in relation to adjacent land. Samplings over the entire paddocks were done to make a complete inventory of all traceable cattle tracks. When a given track was found their location was recorded using the track log function of the GPS handset (Garmin) while walking through the tracks with the equipment turned on.

For assessment of dung pats distribution in the Nature Reserve 2,042 points were recorded and 1,940 points in the Private Area, with approximately 20 m x 20 m distance among them. At each sampling point the observer counted the visible dung pats within the radial distance of 5 m around the point where the observer was located, and recorded the geographic coordinates of the point using the handset GPS (Figure 2).

### Environmental characteristics in both study areas

The geographic boundaries of the areas were recorded using the track log function of the GPS handset, including the perimeters along which the wire fences surrounded both areas.

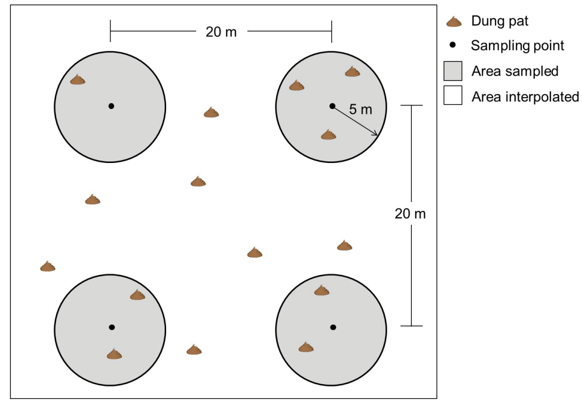


**Figure 2**. Scheme of the method applied for dung pats counting, using a distance of 20 m x 20 m among the points. The sampled area corresponds to 5 m radii around the sampling point, and non-sampled sites were interpolated by kriging. Dung pats locations were recorded once in September 2008 on both studied areas.

Likewise, geographical locations of fences inside the areas and watercourses were registered. The geographical positions of the salt blocks were recorded in the GPS as waypoints. Data for altitudes were recorded with a barometric altimeter in the GPS handset system at the same transect points used for counting dung pats. The prevalence of woody vegetation cover was characterized through satellite images, obtained from http://kartor.eniro.se/ in October 2008.

### Maps composition

A Geographic Information System (GIS) was used for storage, processing and analyzing data, applying the Idrisi Taiga software, version 16.0 (Clark Labs). Three techniques were used to assemble the spatial data into layers:

1) Vector data (punctual or linear, such as tracks, fences, water sources and salt block) had their X and Y geographic coordinates imported directly from the GPS handset into the Idrisi database, and the layers for its spatial location were generated. For spatial multiple regression analyses the data generated as vectors were transformed into rasterized data, creating layers of distance values (in meters, with the pixel size of 1 per 1 m) among each pixel on the map and the assessed characteristic, using the DISTANCE module of ldrisi, that calculates the Euclidian distance of each cell to the nearest of a set of target cells as specified in a separate image (Eastman, 2009).

2) For rasterized data (distributed throughout the area, as dung pats and animals' sightings),

geographic coordinates for the sampling points were initially imported from the GPS handset into GS+ software (Gamma Design Software, 2000). In GS+ spreadsheets, the respective numbers of dung pats for each sampling point were manually assigned. The layers of dung pats distributions were then generated as rasterized data. The spatial files were interpolated by kriging (with the pixel size of 1 per 1 m), using GS+, in order to estimate values in sites not sampled. The same procedure was carried out to generate the spatial dataset of animals' sightings. Finally, these maps of distribution were imported into the Idrisi database for the spatial statistical analyses. The module SLOPE was used to generate the slope layers, by calculating the slope (in degrees) based on differences of altitude between each adjacent point in the terrain.

3) Satellite images from Nature Reserve and Private Area were imported into Idrisi and were geo-referenced using known points in the areas, with RESAMPLE module, which is used to geo register an image to a reference system or to another file (Eastman, 2009). The prevalence of woody vegetation cover was characterized according to the color differences in the gray-scale image generated by satellite photo. To perform image reclassification and define the classes of vegetation cover the module RECLASS of Idrisi was used, as follows: 1) forest: continuous areas with at least 1 ha covered by woody vegetation, 2) grassland with trees: grassland with less than 1 ha covered by one or more trees and shrubs, and 3) open grassland: grassland areas without trees and shrubs. The area of each class of vegetation cover was assessed using the AREA module of Idrisi that calculates the area of a variety of units of each class in an image (Eastman, 2009).

### Data analyses

Due to several differences between the two pastures (size, shape, animal densities, and vegetation cover), the statistical analysis were conducted separately for each area.

Dispersion indexes (DI) were calculated for the indicators of land use, using the ratio between the variance and the mean frequency of observation for each of the three indicators, through QUADRAT module of Idrisi (Eastman, 2009). Three patterns of distribution were defined: uniform (DI $< 1$), random (DI $= 1$), and aggregate (DI $> 1$) (Krebs, 1999). The percentages of animals' sightings, dung pat concentration and the percentages of cattle tracks were assessed according to the classes of vegetation cover (forests, grassland with trees or open grasslands) using the HISTO module of Idrisi (Eastman, 2009).

Spatial coefficients of correlation (r) were calculated among the three indicators of land use (distribution of animals' sightings, cattle tracks and dung pats), using the REGRESS module of Idrisi (Eastman, 2009).

In order to assess the relationship of the land use indicators (as dependent variables) with the environmental characteristics (as independent variables), a multiple spatial regression was conducted, using the Idrisi MULTIREG module, which performs a multivariate regression analysis between images, one dependent variable and two or more independent variables (Eastman, 2009). With this analysis, it was possible to identify among the independent variables, which was the most useful to explain the behavior of the dependent variables. The following equation was used:

$$[1]\ Y_{ijklmn} = \mu + \alpha_i + \gamma_j + \delta_k + \varphi_l + \kappa_m + \varepsilon_{ijklmn}$$

where: $Y_{ijklmn}$ = dependent variable (animals' sightings and dug pats distribution - in number per $m^2$ - and distribution of cattle tracks, m $ha^{-1}$), $\mu$ = overall mean of dependent variable, $\alpha_i$ = $i^{th}$ slope, $\gamma_j$ = $j^{th}$ distance from fences, $\delta_k$ = $k^{th}$ distance from trees, $\varphi_l$ = $l^{th}$ distance from water source, $\kappa_m$ = $m^{th}$ distance from salt block and $\varepsilon_{ijklmn}$ = random error.

## Results and discussion

### Characterization of land use by cattle

Direct observation of animals' location in both areas revealed higher frequencies of occupation in open grassland (83 and 75% of the sightings in Nature Reserve and Private Area, respectively), and lower utilization of the forests (8 and 5% of the sightings in both areas, respectively). It is worth to repeat that open grassland covered 67 and 71% of the total areas, whereas the forests covered 25 and 6% of the total area in Nature Reserve and Private Area, respectively, indicating that cattle preferred to stay at open grasslands during daylight. Mean inclination of the occupied areas was 8.66° in the Nature Reserve and 10.35° in the Private Area, values lower than the mean slope of these two areas, which were 10.17 and 13.10°, respectively. In both locations, the animals were distributed in aggregated form (Figure 3), with a dispersion index of DI = 8.71 for Nature Reserve and DI = 10.17 for Private Area.

In both areas dung pat concentration was higher in open grassland (Nature Reserve: 1.48 ± 1.30 pats 100 $m^2$ and Private Area: 3.53 ± 3.20 pats 100 $m^2$) than under the crown of isolated trees (Nature Reserve: 1.27 ± 1.17 and Private Area: 2.79 ± 2.71

pats 100 m$^2$) and forests (Nature Reserve: 0.96 ± 1.02 and Private Area: 0.31 ± 0.80 pats 100 m$^2$). However, aggregated distribution of dung pats was found only at the Private Area (DI = 2.28), whereas it had a uniform distribution in the Nature Reserve (DI = 0.90), as shown in Figure 4.

Cattle tracks were more concentrated in the Private Area (902.90 m ha$^{-1}$) than in the Nature Reserve (708.63 m ha$^{-1}$), with 27.43 and 45.09 km of total length per area, respectively. Cattle tracks were located predominantly in open grassland within the Private Area, with only 8% of occurrences of cattle tracks in the forests; while in the Nature Reserve 51% of the tracks were recorded in forest areas or near them (up to 7 m away from the forest borders) (Figure 5).

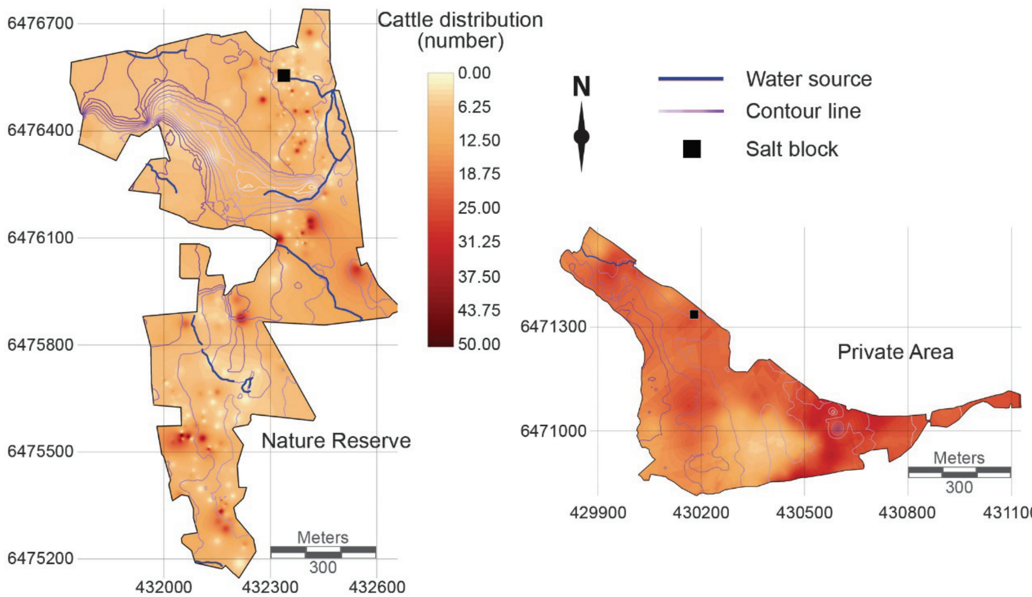


**Figure 3.** Maps of cattle distribution in both study areas (Nature Reserve and Private Area) located in Southwest Sweden. The direct observations of cattle location in the areas were carried out from July to October 2008. Water sources, contour lines and salt block locations are also shown.

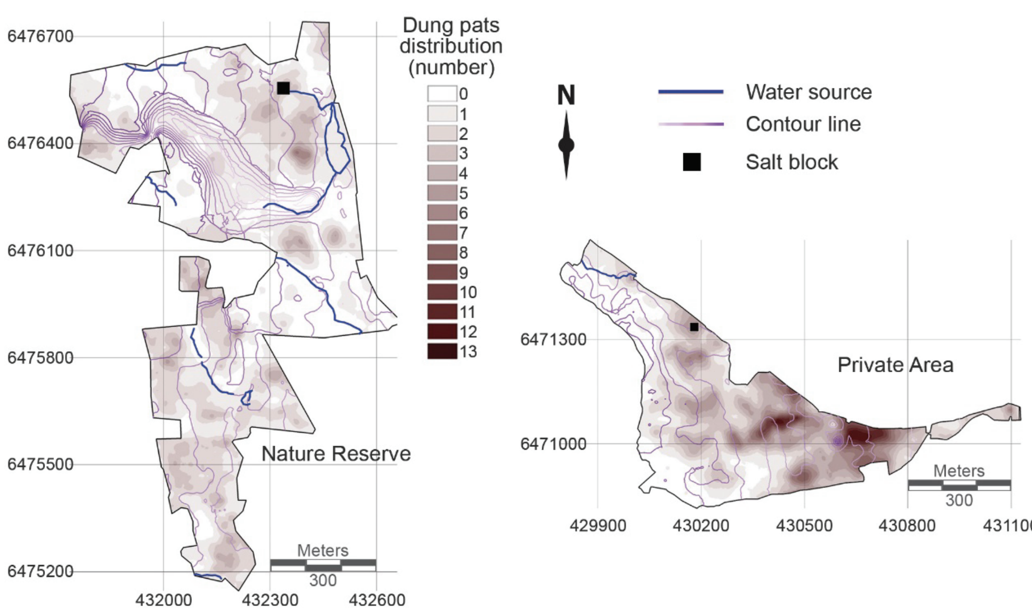


**Figure 4**. Maps of dung pat distribution in both study areas (Nature Reserve and Private Area) located in Southwest Sweden. Dung pat locations data were recorded in September 2008. Water sources, salt block locations and contour lines (contour interval = 10 m) are also shown.

However, the rates of tracks per unit of area were similar for the three vegetation cover types, as follow: Private Area, forest = 878.18 m $ha^{-1}$, isolated trees = 1,266.50 m $ha^{-1}$ and, open area = 781.35 m $ha^{-1}$; Nature Reserve, forest = 852.91 m $ha^{-1}$, isolated trees = 572.74 m $ha^{-1}$ and, open area = 623.51 m $ha^{-1}$. In the Nature Reserve the mean slope in the sites with tracks was 7.4°; while in the Private Area, sites with tracks had slightly higher slope (9.1°). These values were lower than the mean inclination of the lands. In both areas, the location of cattle tracks was uniformly distributed (Nature Reserve: DI = 0.98 and Private Area: DI = 0.97).

Spatial correlations between the three indicators of land use (distribution of animals' sightings, dung pats and cattle tracks) were all low, suggesting that the three indicators used reflected different aspects of land use by cattle (Table 1).

**Table 1** Spatial correlations coefficients (*r*) between the three indicators of land use (distribution of animals' sightings, dung pats and cattle tracks). Above diagonal values from Private Area and below from Nature Reserve.

| Indicators | Animals' sightings | Dung pats | Cattle tracks |
|---|---|---|---|
| Animals' sightings | - | 0.00 | -0.18 |
| Dung pats | 0.00 | - | 0.22 |
| Cattle tracks | 0.08 | 0.13 | - |

These differences have to be considered when interpreting the results obtained with these methods. For instance, direct observation of the animals enables to identify the variations of land use by cattle in a specific moment or, after consecutive assessments, and it enables estimation of differences in the occupancy rate among certain sites over a studied area. In turn, dung pat distribution contributes to the understanding of land use by cattle over a longer period (not in a specific moment), given that they can remain in the pasture during a long term. In this case, the possibility of identifying sites in the area with different rates of occupancy could be dependent on several characteristics of the studied area, for example its size and stock density. Regarding cattle tracks, they are useful for determining the main sites of cattle movement, and their location can be characterized as a long-term indicator of land use. However, tracks do not offer any valuable information to estimate the occupancy rate in terms of length of stay, probably leading to a uniform distribution over the areas. Land use indicators must be chosen according to the aims of the study, as all of them are able to yield valuable information on this subject, with inherent advantages and limitations.

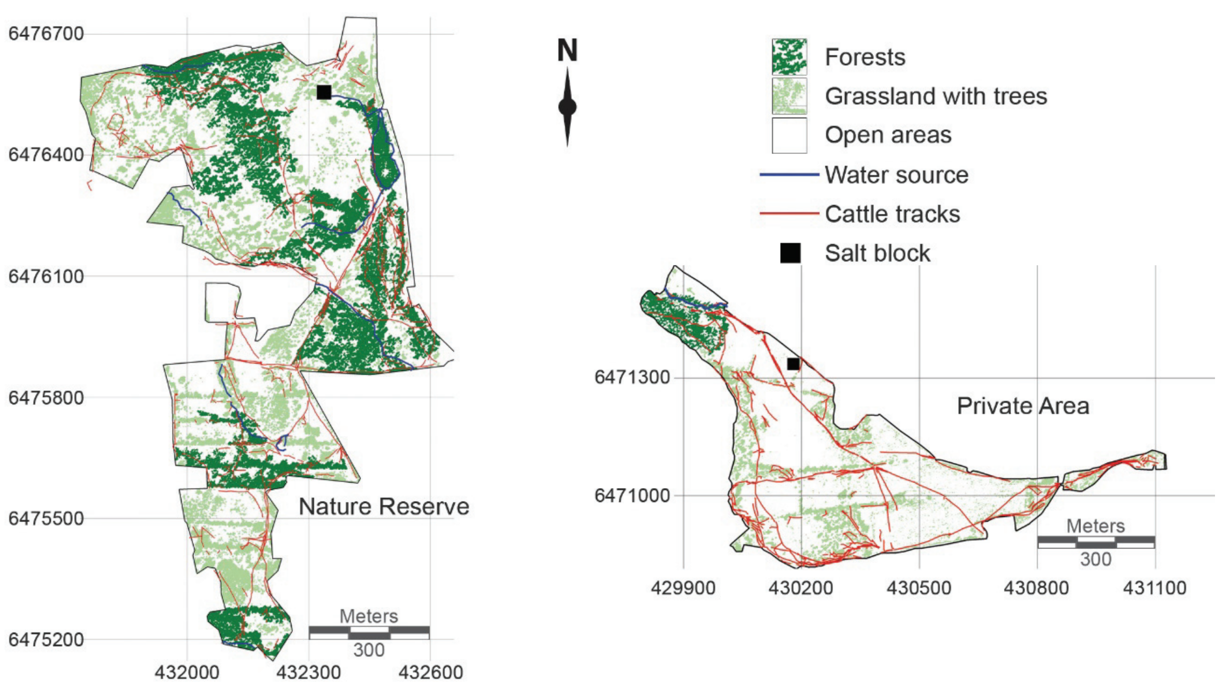


**Figure 5.** Maps of cattle tracks distribution in both study areas (Nature Reserve and Private Area) located in the Southwest Sweden. Data for cattle track locations were recorded in September 2008. Water sources, salt blocks, grassland with trees and forests locations are also shown.

### Predictive power of environmental factors for the three indicators of land use

In Nature Reserve, the environmental characteristics explained 20% of the variability in the distribution of dung pats ($F$ = 32,503, $R$ = 0.45), 10% of the distribution of cattle tracks ($F$ = 14,795.825, $R$ = 0.32), and only 5% of the distribution of animals ($F$= 6,176.462, $R$ = 0.21), as shown in the regression equations from [2] to [4], ($p$ < 0.01 for all of them). The same pattern was observed in Private Area, although the predictive value of the environmental characteristics was slightly higher, explaining 33% of the variability in the distribution of dung pats ($F$ = 29,860.195, $R$ = 0.57), 20% of the distribution of tracks ($F$ = 15,027.893, $R$ = 0.44) and 7% of the distribution of animals ($F$ = 4,935.562, $R$ = 0.27), as shown in the equations from [5] to [7], ($p$ < 0.01 for all of them).

[2] DDP = 0.2289 – 0.0051*SL + 0.0018*FE + 0.0758*TR + 0.0044*WS + 0.0005*SB;
[3] DT = 15.2683 – 0.0143*SL + 0.0522*FE + 0.6018*TR + 0.0463*WS – 0.0091*SB;
[4] DA = 7.6884 – 0.0297*SL + 0.0050*FE + 0.0118*TR +0.0052*WS – 0.0016*SB;
[5] DDP = 0.1353 – 0.0097*SL + 0.0039*FE + 0.0437*TR + 0.0056*WS – 0.0027*SB;
[6] DT = 7.5578 – 0.0423*SL + 0.0621*FE + 0.3110*TR – 0.0098*WS + 0.0126*SB;
[7] DA = 22.3054 – 0.2999*SL – 0.0050*FE + 0.0155*TR + 0.0029*WS – 0.0068*SB;

where: DDP = distribution of dung pats (number of dung pats per $m^2$); DT = distribution of tracks (in m $ha^{-1}$); DA = distribution of animals' sightings (number of animals per $m^2$); SL = slope (in degrees); FE = distance from fences (in m); TR = distance from trees (in m); WS = distance from water source (in m); SB = distance from salt block (in m).

The individual coefficients in the equations indicate the degree of relative contribution by each independent variable. Among them, slope and distance from trees had greater effects on the distribution of dung pats and animals; while fences and salt blocks had the lowest contributions in both areas. The distance from water sources had an intermediate contribution in the Nature Reserve; while in the Private Area, a lower contribution was found. Moreover, the distribution of cattle tracks was more influenced by fences and trees in both areas; whereas slope, water sources and salt blocks had minor contributions.

With respect to the distribution of animals' sightings, slope was the environmental characteristic with the highest influence on land occupation in both areas, corroborating previous findings that reported a preference of cattle for sites with reduced slope (Ganskopp & Bohnert, 2009; Kaufmann, Borka, Blenis, & Alexander, 2013). A clear trend of higher occupancy in open grasslands was also found, compared to the other vegetation types, which made the trees appear among the most important environmental characteristics in predicting the distribution of animals' sightings. In the Nature Reserve, forests covered 25% of the area and the proportion of animals' sightings in forest was 8%, whereas the open areas occupied 67% of the area and the proportion of sightings was 83%. If we consider that preference of a given habitat can be defined as the disproportionality between the ratio of use and its availability (Aarts, MacKenzie, McConnell, Fedak, & Matthiopoulos, 2008), these results indicate disproportionality between the availability of the open area and its use. The same trend was found in the Private Area, but with a lower disproportionality between use and availability of open area, which covered 70% of the area and the proportion of animals' sightings represented 75% of the total. The higher distribution of animals' sightings in open grasslands could be explained by the greater frequency of grazing activity during the daylight (Schlecht et al., 2004) along with the cattle's preference for grazing in open areas (Miguel et al., 1997). A previous study assessing habitat selection in a heterogeneous Montane environment in Canada, the authors found a marked preference for grasslands in comparison to conifer forest, suggesting that cattle select habitats in order to optimize the forage intake, i.e. habitats providing the most biomass, in these cases the grass (Kaufmann et al., 2013). Thus, although it is possible that the animals in the present study had not actually used the forests for grazing during daylight (period of behavioral observations), we cannot rule out the possibility that these areas were grazed during the night, when there was no direct behavior sampling.

In fact, the low concentration of dung pats in forest areas observed in both pastures indicate that these sites were used at some time during the 24 hours of the day, but with a lower occupancy rate than for open grassland. This result demonstrates a possible bias in the sampling method of direct observation, due to potential differences in the land use as a result of the time of the day at which the samplings are done, e.g. during active foraging periods (during daytime), compared to other periods (crepuscular and nocturnal), when the direct observations were not carried out. The use of GPS collars would be a useful tool to identify the environmental factors affecting land use by cattle at night. However, to date, most of the studies using this technology did not consider analyzing the data according to the time of the day (Schlecht et al., 2004; Putfarken et al., 2008; Orr et al., 2012), and the one that considered (Anderson et al., 2011) did not discuss the effects of environmental factors on land use according to the periods of the day.

With respect to the distribution of dung pats, the predictive power of environmental characteristics was higher than for the others land use indicators. In the Private Area, dung pats had an aggregated distribution, concentrating mainly in open grasslands, in accordance with the distribution based on direct observation. By contrast, in the Nature Reserve dung pats were evenly distributed throughout the pasture and were distributed similarly in the open grasslands and in grasslands with trees. The two areas differed in a set of characteristics, making difficult to identify which of them leads to the differences found on the patterns of dung pats distribution between the areas. One important factor affecting the variation in the dung pats distribution over a pasture is the stock density (Vendramini, Dubeux, & Silveira, 2014); thus, we can infer that the lower stock density in Nature Reserve than in Private Area may have contributed to the different patterns found. Additionally, in both areas dung pats concentration was higher in regions with lower slopes, areas of resting and moving (e.g. along fence lines), confirming the results of previous studies using the distribution of dung pats as indicator of land occupation (Tate et al., 2003; Hirata et al., 2009).

In its turn, cattle tracks had uniform distribution over both areas, and the environmental characteristics had low power on its prediction. The distribution of cattle tracks was similar for the three vegetation types, with a slightly higher length of tracks per ha in areas with isolated trees and forests, than in open areas. The visual analysis of Figure 5 confirms these results, with the addition of two interesting findings: when cattle used the open areas and forests for transit, the tracks were predominantly located in the boundaries of these two vegetation types, and several cattle tracks were close to the fences, resulting that 'fences' were the second most important environmental factor determining cattle tracks distribution. There was a low predictive power for slope in the distribution of tracks, which differs from the results of Ganskopp et al. (2000), who described an important role of slope in determining tracks used by the animals. The authors provided evidence that this would be a strategy used by animals to reduce energy expenditure during their displacement in steep slope areas. One possible explanation for the low predictive value of slope in the distribution of cattle tracks found in our study was the lack of alternative routes, especially in the Nature Reserve; therefore, under such condition cattle was not able to avoid walking in terrains with high slope. The low predictive power does not reduce the environmental importance of this indicator, since the formation of tracks on slopes could feature a major risk factor for soil compaction, leading to reduction in soil porosity and infiltration capacity, consequently, the occurrence of erosion and sediment accumulation on natural water sources (Tate et al., 2004; Bezerra, Etchebehere, Saad, & Casado, 2009).

In general, the more permanent character of cattle tracks and dung pats leads to different temporal scales of land use assessments when using indirect indicators in relation to those assessed by direct observation of animals. For example, cattle tracks could reflect the occupation over a long period, even years, while the dung pats are likely to give information from few days to the whole grazing season (Hirata et al., 2009), in this case the summer 2008, because during winter the Nature Reserve and Private Area were not occupied by cattle. On the other hand, when using the direct observation of the animals we recorded information restricted to the sampling period and, it was subject to reduced sampling efficiency in forest areas, because of incomplete sightings of the animals. This could explain situations (28% of the observation sessions) in which we were not able to find all the 53 individuals of the group in the Nature Reserve, which has 15.89 ha of forest area.

The alternative method to perform the direct observations of free ranging cattle is the use of GPS collar technology, but its outcomes would also be subject to this effect, as despite the important advances of this technology over the last years, increasing location accuracy, the location erros and fails under canopy of trees is still a cause of concern (Anderson, Estell, & Cibils, 2013). According to Camp, Rachlow, Cisneros, Roon, & Camp (2016), GPS collars' performance was less reliable in areas with greater canopy cover when compared with others vegetation covers, generating location errors of 8.1 ± 4.12 m in habitats with grass vegetation, 9.0 ± 4.34 m in shrubs, and 11.1 ± 4.34 m in areas covered by trees. The magnitude of vegetation type influence can be even more concerning, since Agouridis et al. (2004) reported GPS collars location errors of the order of 2.5 times greater in forest areas when compared with the error in open areas.

Finally, the low predictive power of environmental characteristics may have occurred due to lack of one or more factors that affected land use patterns, not accounted in the present study. The major abiotic components associated with the spatial distribution of cattle in previous studies (Hirata et al., 2009; Kaufmann et al., 2013) were included in this study. Nevertheless, it is likely that other biotic environmental factors had played overwhelm influence on land use by animals, in special the forage characteristics (such as botanical composition, herbage biomass and protein concentration), described as major factors affecting land use by cattle in heterogeneous environments (Ganskopp & Bohnert, 2009; Kaufmann et al., 2013).

## Conclusion

The three methods to assess land use by cattle (distribution of animals' sightings, dung pats and cattle tracks) were weakly associated, leading us to conclude that each method addresses different characteristics of land use by animals and that, due to this, land use indicators must be chosen according to the aims of the study as all of them are able to yield valuable information on this subject. We also concluded that the environmental factors assessed (in particular the woody vegetation cover and terrain slope) presented higher power to predict dung pats distribution than cattle tracks and animals' sightings.

## Acknowledgements

Appreciation is expressed to Anna Lundberg and Linda Keeling, SLU. Also, we thank the Swedish Board of Agriculture for funding (Process: 31-7070/07).

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*Received on February 14, 2017.*
*Accepted on May 24, 2017.*