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Presenter Information

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Rangelands Vegetation mapping at Species Composition level using the SPiCla method: SDM based Pixel Classification and fuzzy accuracy. A new approach of map making.

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Key words: [SPiCla; rangelands vegetation map; floristic composition; SDM; NDVI; fuzzy accuracy]

Abstract

Vegetation maps have been made since centuries. The vegetation cover was represented as homogeneous mapping units (polygons), representing different vegetation types, where each type consists a combination of different plant species (floristic composition). More recent, with the use of satellite imagery, the polygons have been replaced by pixels with similar content as the polygon maps. In both approaches, field-observations were linked to the mapping units (polygons or pixels) often resulting in a complex of different vegetation types per mapping unit. In our new approach field data (sample points) on presence and abundance of individual grass species are spatially extrapolated based on a set of environmental layers, using the species distribution modelling approach (SDM). When combined, each pixel will contain its own set of information about the vegetation structure and its floristic composition. This new methodology (SPiCla) results in a very accurate and detailed vegetation map at pixel level, allowing extraction of very detailed, accurate and easy to update spatial information on e.g., forage production and quality (palatability) for rangelands management. As no exact boundaries exist, but only gradients, we introduced fuzzy accuracy. The resolution mainly depends on the resolution of (or one of) the environmental layers used, scale of interest and workability. The methodology is generic and applicable to any other region in the world.

Introduction

Vegetation maps, especially in rangelands, are often based on complexes of different grass species with varying abundances and cover percentages. Variations in the spatial distribution of the rangelands vegetation types and species abundances and cover are often influenced by rainfall, soil and relief (Reed et al. 2009). These maps can be used for rough estimations of grasslands quality, but for more reliable estimations mapping units with complexes of different species with different palatability are often too general and coarse for accurate estimations of species composition, and palatable biomass production. Given the importance of these variables in management of rangelands, this paper describes a generic method for the compilation of a detailed map containing at pixel level both the structural – and the floristic composition of the vegetation.

Methods and Study Site

The Maara Middle Basin is a typical example of a savannah ecosystem (Braun and Mungai 1981) in East Africa. The vegetation of the Maara plains can roughly be divided into woodland, bushland and grassland (Pratt and Gwynne 1977). Grasslands are predominant in the plains, while forest is mostly confined to hill crests and along the main rivers. *Chloris* spp. and *Sporobolus* spp. dominate the grasslands on basement rocks, *Pennisetum* spp. dominate on the volcanic soils in the South East. The south western part receives more rainfall and is dominated by *Themeda triandra*, while *Pennisetum mezianum* is common on the floodplains. Several grassland types include dwarf shrubs and perennial herbs, important browse plants for sheep and goats (Wijngaarden, W. van 1985).

First a preliminary stratification of the Maara Middle Basin was produced, by applying the hyper-temporal NDVI classification method (de Bie et al. 2012; Westinga et al. 2020), using 16-day composite of MODIS-Terra NDVI images (vegetation greenness index rescaled from 0 to 255 DN-Values) from January 2000 to December 2013. The classification result formed the basis for a stratified random field-sampling scheme, with emphasis on the grasslands. Fieldwork was done in October 2014 (65 samples), May 2015 (62 samples) and October 2016 (171 samples), covering both the wet and dry season. Validation of the final vegetation map was done in February 2019 (58 samples). In each sample site data on land cover, vegetation structure, grass species composition and abundance were collected. The field data were grouped in to floristic vegetation types according the Braun-Blanquet method (Braun-Blanquet 1932) and the classification result was summarized in a synoptic table (see table 1).

To be able to produce a very detailed and accurate vegetation map at pixel level, the species distribution modelling (SDM) approach was applied (Elith and Leathwick 2009). It is pivotal to select those environmental parameters bearing significance for the environmental requirements of each grass species. The following

parameters were selected: Altitude (m) and Relative Altitude (m), Slope (%), Rainfall (mm/year), NDVI-71 classes, NDVI-median, NDVI-SD and NDVI-trend. Both altitude and relative altitude were used. Relative altitude is crucial to be able to discriminate small hill-tops from depressions, as this can make a big difference in grass species presence and abundance due to difference in texture and or soil moisture. Discriminating NDVI data of MODIS-Terra satellite imagery (NASA, 2014, Lu et al., 2015) are: NDVI-71 classes is the classified hyper-temporal image, NDVI-median the long-term Median of all NDVI measurements by pixel, indicating the spatial differences in overall greenness of the vegetation, NDVI-SD which is the long-term Standard Deviation of all NDVI measurements by pixel, indicating the difference in greenness of the vegetation during seasons and years and NDVI-trend which is the long-term Trend of sequential NDVI measurements by pixel, indicating the gradual (16-daily) overall change in greenness of the vegetation during the 14 years studied.

The pixel size was set to 23 meters square., The MODIS products have a rectangular pixel size of 230 meters, so the pixel was divided by 10 reducing the error of the value at the outer edges. All other variables were rescaled to the same pixel size. The field sample locations were used for the grass species occurrence points. Each of the 19 most common grass species had a separate sample set and a “probability of occurrence” map was created using Maxent (Phillips et al., 2006), with a probability ranging from 0 to 100. These probabilities were rescaled from 0 to the maximum cover (%) measured during field sampling, resulting in 19 maps with a predicted grass cover of 0% up to their maximum cover % (Figure 1).

When combining these 19 predicted grass cover maps, the summed cover percentage at any sample location should correspond with the total grass cover percentage as estimated in the field. The summed “probability” map contains at any location (pixel) a combination of grass species, with a certain cover per species, which should also correspond with the sampled combination of grass species collected in the field. Finally, when clustering the many combinations resulting from the 19 combined probability maps in ERDAS (Nelson and Khorram, 2018), the number of vegetation classes in the final clustering is corresponding with the result of the floristic composition, based on the field data (Table 1).

Validation is done by taking the average AUC of each AUC belonging to each grass species probability within a grasslands class (type) weighted to the % of occurrence of that species in that grassland type (Mas et al., 2013). When summing the average AUC of the 10 grassland types the overall accuracy of the whole vegetation map has been calculated.

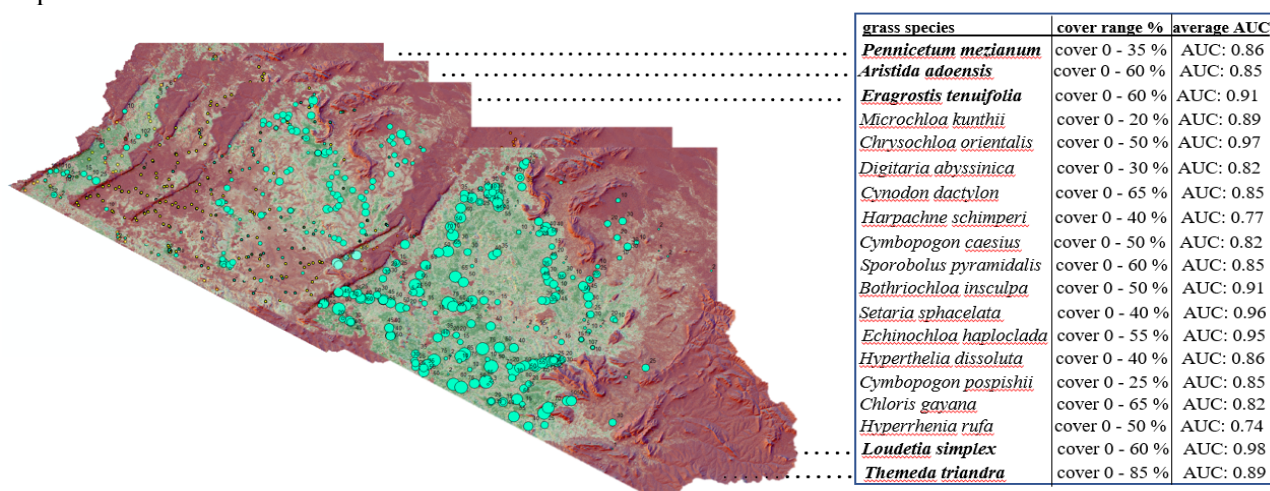


Figure 1: The predicted grass cover maps with their cover range and accuracy of the prediction (average AUC of the total nr runs/species). Green dots represent the grass species samples, sized to relative cover percentage.

In nature crisp boundaries are rare, as presence and abundance of species change gradually, sometimes more sometimes less. Hence, the accuracy can never be exact, as it is a resultant of a gradient, a value range of densities of a mix of classes. Furthermore, in one (wetter) year the densities can be different from another (drier) year or season. Therefore, when checking the accuracy of the vegetation map with field observations, the results will be a proxy to reality and therefore “fuzzy accuracy” has been used as a measure of accuracy. The term fuzzy classification was used before (Reed et al., 2009), describing the accuracy of the vegetation structure classification. Here we are validating the floristic composition of the vegetation types (Table 1). The central pixel of the 58 validation field-samples, taken in February 2019, was compared with the same classified pixel in the vegetation map. Furthermore, the 9 surrounding pixels of the validation sample are also checked and averaged as was done with the surrounding 25 pixels. For each field sample the % match/mismatch with the dominant grass species in that vegetation type in the map has been estimated. When the dominant grass species are the same, a 100% match is assumed. When more dominant grass species are present, but not

belonging to that vegetation type, or a dominant grass species is missing, it will reduce the 100 % match according to the total number of dominant grass species.

Results

The final result was a digital high-resolution rangelands vegetation map, with emphasis on the grasses (Figure 2 and <http://mara.rangelands.itc.utwente.nl/>). The map is scale independent with a resolution of 23 meters square. Each pixel is representing a vegetation type (e.g., G1, G2, etc) according to Table 1, representing a certain floristic composition and abundance (cover %) of the present grass species in the selected vegetation type. Tracks and drainage have been added to the map. The floristic groups with the average of the observed cover % per grass species together with the vegetation structure are shown in Table 1.

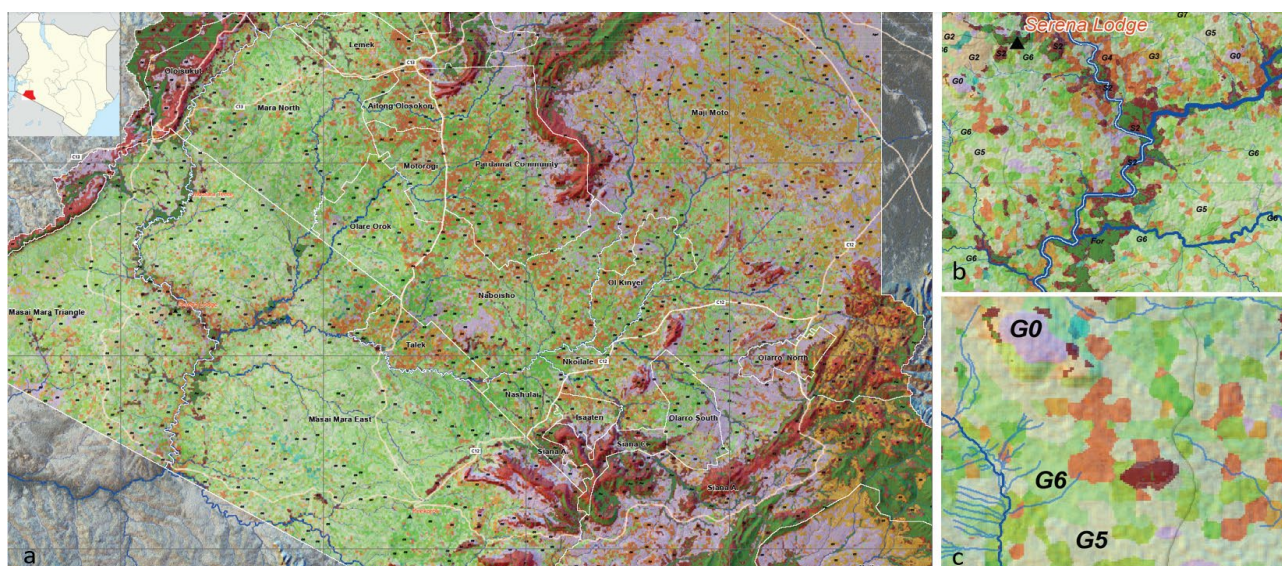


Figure 2: The final grasslands vegetation map at pixel level (a). Each pixel represents a vegetation class according to Table 1. The cut-outs (b and c) show a detailed part of the map where pixels can be distinguished separately (when not clustered).

vegetation type		G0	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
structure	grass cover (%)	(20) 15 (5)	(35) 45 (65)	(35) 45 (60)	(25) 70 (95)	(25) 60 (85)	(50) 85 (100)	(35) 80 (100)	(70) 85 (100)	(40) 65 (90)	(60) 90 (100)	(45) 75 (100)
	bare soil (%)	(40) 75 (90)	(20) 35 (50)	(25) 35 (55)	(10) 20 (30)	(20) 50 (75)	(7) 20 (35)	(0) 25 (70)	(3) 10 (20)	(0) 5 (7)	(0) 25 (35)	(7) 20 (35)
	tree cover (%)	0	(0) 3 (7)	0 (3)	0 (3)	0 (3)	0 (3)	0 (3)	0 (3)	0 (3)	0 (3)	0 (3)
	high shrub cover (%)	2	(0) 5 (15)	0 (3)	0 (3)	0	(0) 3 (7)	(3) 10 (15)	0 (3)	0 (3)	0 (3)	2 (3)
	low shrub cover (%)	(3) 4 (7)	(3) 7 (15)	3 (7)	(2) 5 (20)	(0) 5 (15)	(3) 5 (7)	7 (10)	(3) 5 (7)	(0) 3	(3) 5 (7)	(3) 5 (7)
	herb cover (%)	0 (5)	0 (7)	(3) 13 (35)	(0) 5 (7)	(0) 3 (7)	(3) 10 (25)	(0) 25 (35)	(0) 3 (7)	(0) 3	(0) 7 (10)	(3) 10 (15)
	litter (%)	0 (3)	0 (3)	0 (3)	0	(0) 3 (10)	0	0 (7)	0 (7)	0 (30)	0 (7)	0 (7)
stones (%)	0	0	0	0	(0) 3 (7)	0	0 (3)	0 (3)	0	0	0	
vegetation type		G0	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
vegetation type name		grassland (heavily degraded to bare)	<i>Aristida Microchloa</i> with <i>Eragrostis</i> grassland	<i>Chrysochloa</i> with <i>Microchloa</i> and <i>Eragrostis</i> grassland	<i>Chrysochloa Eragrostis</i> grassland	<i>Eragrostis Cynodon</i> with <i>Bothriochloa</i> grassland	<i>Themeda Eragrostis Sporobolus</i> with <i>Bothriochloa</i> grassland	<i>Themeda Cynodon</i> grassland	<i>Themeda Cymbopogon</i> with <i>Sporobolus</i> grassland	<i>Themeda Bothriochloa</i> with <i>Eragrostis</i> grassland	<i>Themeda Setaria</i> with <i>Bothriochloa</i> grassland	<i>Loudetia Setaria</i> grassland
Characteristic species												
grass species	<i>Aristida adoensis</i>	-----	████████	-----	-----	-----	-----	-----	-----	-----	-----	-----
	<i>Microchloa kunthii</i>	-----	████████	-----	-----	-----	-----	-----	-----	-----	-----	-----
	<i>Chrysochloa orientalis</i>	-----	-----	████████	████████	████████	████████	-----	-----	-----	-----	-----
	<i>Eragrostis tenuifolia</i>	-----	-----	-----	████████	████████	████████	-----	-----	-----	-----	-----
	<i>Pennisetum mezianum</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	<i>Digitaria abyssinica</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	<i>Cynodon dactylon</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	<i>Harpachne schimperii</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	<i>Themeda triandra</i>	-----	-----	-----	-----	-----	████████	████████	████████	████████	████████	████████
	<i>Cymbopogon caesius</i>	-----	-----	-----	-----	-----	-----	-----	████████	████████	-----	-----
	<i>Sporobolus pyramidalis</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	<i>Bothriochloa insculpta</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	<i>Setaria sphacelata</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	<i>Loudetia simplex</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	████████
	<i>Echinochloa haploclada</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
<i>Hypertheria dissoluta</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
<i>Cymbopogon pospishiii</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
<i>Chloris gayana</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
<i>Hyparrhenia rufa</i>	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
other species	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	

Table 1 : Structural cover and floristic groups (vegetation types) with average of the observed cover percentage per characteristic grass species, where solid-black is the dominant species, solid grey is co-dominant (cover >20%) and always present, broken solid grey co-dominant (cover <20%) but not always present, grey dots represents high cover (>20%), but sometimes present. Solid line has low cover (<20%), but always present, broken line low cover and not always present and dotted line low cover (<5%) and sometimes present.

The average AUC of the probability maps of the 19 combined grass species was 0.87 (+/- 0.03 %) at 95% confidence level, ranging from 0.77 to 0.99 (Figure 1). So based on these results the input maps can be considered as highly reliable. The fuzzy accuracy of the map, when checking with the validation field samples was 80% (+/- 7.2% at 95% confidence level), when analysed on pixel to pixel. Taken surrounding pixels in consideration, the 3x3 and 5x5 matrix had a fuzzy accuracy of respectively 78% (+/- 7.6%) and 76% (+/- 7.6%), also both at 95% confidence level, meaning the floristic composition in the produced vegetation map is at pixel level most accurate.

Discussion

When applying the SPiCla approach, using SDM, it is possible to create a vegetation map with a very high resolution without any complex of different vegetation types, meaning each pixel has its own structural cover and floristic composition classification. No satellite data is needed as direct input for the classification, only needed as parameter input for the probability modelling. As no exact boundaries exist, but only gradients, we introduced fuzzy accuracy. Based on the results of the fuzzy accuracy tests the results can be considered very reliable, noting that the classification of the floristic composition is even included. The SPiCla method is an unique approach and gives a result at pixel level, so spatially very accurate, which can be easily updated using recent NDVI data, makes it also possible to estimate e.g., forage productivity for rangelands management including the palatability of the forage or the condition of the rangelands. The resolution is in principle unlimited and depending mainly on the resolution of (one of) the environmental parameters used, scale of interest and workability. The SPiCla method is facilitating management and conservation already in the Maara Middle Basis (<https://www.youtube.com/watch?v=iGc22qVMrGg>). The SPiCla method is generic and applicable for any other region in the world.

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