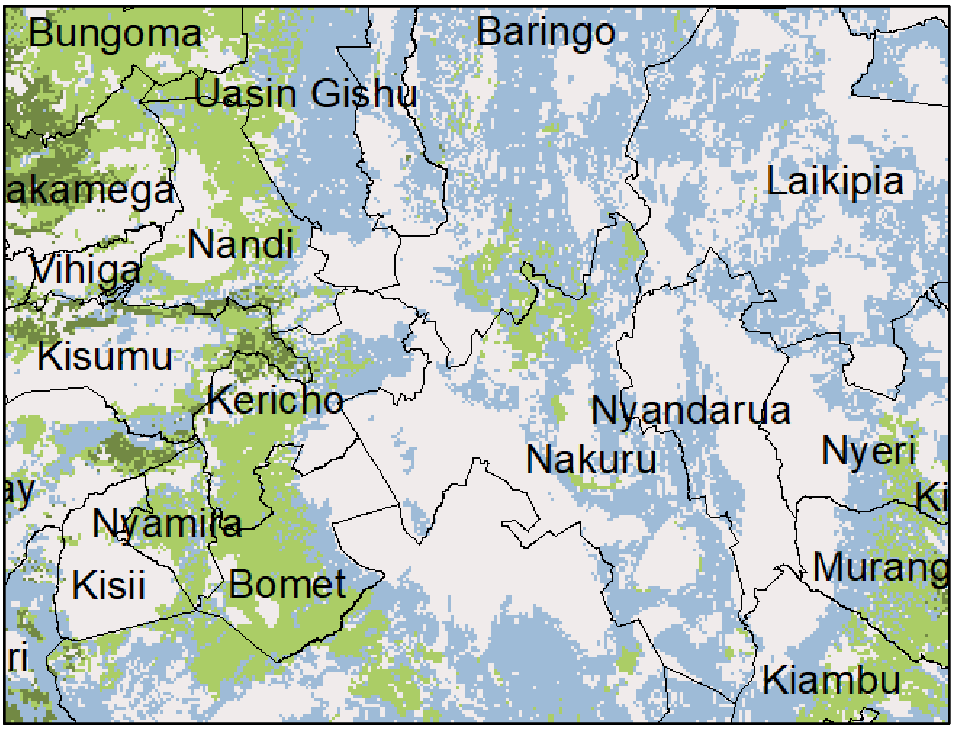
Zurich University
of Applied Sciences

Life Sciences and
Facility Management

Institute of
Natural Resource Sciences

ASSESSING SOYBEAN PRODUCTION IN KENYA

Land suitability evaluation for soybean using CONSUS



July 2018 · Final Report

CONSUS
Connecting for Sustainable Sourcing

Table of contents

Dr. Roman Grüter
Research Associate at Geography of Food research group

Institute of Natural Resource Sciences
ZHAW Zurich University of Applied Sciences
Grüental, Postfach, CH-8820 Wädenswil

Phone +41 58 934 53 71
Email roman.grueter@zhaw.ch
Homepage www.zhaw.ch/iunr/gof

1 Introduction

Soybean (*Glycine max* L.) is one of the world's major crops with a global production of more than 300 million metric tons in 2017. The crop's share in global oilseed output is estimated at over 50%. Soybean production in Africa however is less than 1% of global production.

The Kenyan animal feed and foodstuffs industry consumed about 101 thousand metric tons of soybean grain in 2017 with an annual growth of about 2%. More than 90% of soybean demand is imported and there is little local production. However, soil and climatic conditions in Kenya are potentially suitable for soybean production.

Soybean is known to have a high protein content and is mainly grown for livestock feed and edible oil. As a leguminous plant, it has the potential to fix atmospheric nitrogen and improve soil fertility. Its integration into crop rotations can also be beneficial for reducing pathogen pressures.

In this study, the suitability of agricultural land in Kenya for soybean cultivation is evaluated using CONSUS (Jaisli et al., 2018) based on current soil and climatic conditions. By matching soybean requirements with global and regional datasets about biophysical parameters, suitability maps are generated and most promising production sites and major limitations identified.

2 Methods

CONSUS modules 1 (climate) and 2 (soil & landscape) were applied to evaluate land for soybean production in Kenya using the geographic information system software ArcGIS. Soybean requirements (Table 1) and classification into four suitability classes (S1: very suitable, S2: moderately suitable, S3: marginally suitable, N: unsuitable) were based mainly on Sys et al. (1993). Publically available global and regional datasets (Table 1) were used to describe the climatic, soil and landscape conditions of Kenya on a 30 arc second resolution. Through matching the soybean requirements with the site description on every grid cell, suitability of all climate, soil and landscape parameter was evaluated. The information was then aggregated using the maximum limitation method to obtain the overall climate, soil and landscape suitability and the overall biophysical suitability.

Monthly data was used to assess the climatic suitability. Therefore, every month was modelled as a starting month for soybean cultivation to find the optimum growing period.

The soil characteristics from the SoilGrids database were available at several soil depths (0, 5, 15, 30, 60, 100, 200 cm). Information at 15 cm depth was used in the CONSUS model because the topsoil layer (0-20 cm) is most relevant for crop growth.

Table 1: Biophysical requirements of *Glycine max* L.

Criteria	Unit	Data Source	S1 (very suitable)	S2 (moderately suitable)	S3 (marginally suitable)	N (unsuitable)
Climate						
Precipitation of the first 4 months	mm	WorldClim	350-1100	250-350 or 1100-1600	140-250 or 1600-1900	<140 or >1900
Mean temperature of growing cycle	°C	WorldClim	20-30	18-20 or 30-35	15-18 or 35-40	<15 or >40
Mean minimum temperature of growing cycle	°C	WorldClim	>12	9-12	7-9	<7
Relative humidity of development stage (2nd month)	%	CliMond	>42	36-42	30-36	<30
Relative humidity of maturation stage (4th month)	%	CliMond	24-75	20-24 or 75-85	<20 or >85	-
Sunshine duration of development stage (2nd month)	n/N	CliMond	0.35-0.75	<0.35 or >0.75	-	-
Sunshine duration of maturation stage (4th month)	n/N	CliMond	>0.5	<0.5	-	-
Soil						
Soil depth	cm	SoilGrids	>75	50-75	25-50	<25
Coarse Fragments	%	SoilGrids	0-15	15-35	35-55	>55
Soil texture	Class	SoilGrids	Cl, SaCl, ClLo, SiClLo, SaClLo, Lo, SiLo, Si	SaLo	SiCl, LoSa	Sa
Soil organic carbon	%	SoilGrids	>1.2	0.8-1.2	<0.8	-
Soil pH		SoilGrids	5.5-7.0	5.0-5.5 or 7.0-7.8	4.5-5.0 or 7.8-8.5	<4.5 or >8.5
Soil salinity (ECe)	dS/m	Harmonised World Soil Database (HWSD)	0-2	2-4	4-5	>5
Landscape						
Slope	%	ESRI Terrain Service	0-10	10-15	15-30	>30
Land cover	Class	FAO Global Land Cover SHARE	Cropland	-	Grassland, Shrubs Covered Areas	Artificial surfaces, Tree Covered Areas, Herbaceous vegetation (aquatic or regularly flooded), Mangroves, Sparse vegetation, Baresoil, Snow and glaciers, Water bodies
Protected areas	Class	World Database on Protected Areas (WDPA)	-	-	-	Protected Areas

3 Results & Discussion

3.1 Overall suitability

Overall, the CONSUS land evaluation for Kenya revealed that the areas suitable for soybean cultivation are concentrated around Western Kenya, the Central highlands and certain areas along the coast (Figure 1).

The total area at least moderately suitable for soybean is most restricted by the landscape suitability, i.e. by the extension of cropland. The majority of cropland areas are further restricted by climatic factors, from the highest (S1) to the second suitability class (S2), in particular due to suboptimal levels of precipitation. In climatically suitable areas, soil parameters such as soil depth or pH, or the landscape parameter slope further reduce the area suitable for soybean cultivation.

As described in chapter 3.2, the suitability is strongly dependant on the sowing date because of the climatic variability during the growing period.

3.2 Climate suitability

The overall climate suitability (Figure 2) represents the highest suitability taking into account every month as a starting month for soybean cultivation. It clearly shows that in the Northeast of Kenya and at the higher altitudes around the Rift Valley, Mount Elgon and Mount Kenya the climate is not or only marginally suitable for soybean cultivation. On the other hand, the climate is suitable at Western, Central and Coastal Kenya.

The climate variable that determines the suitability most is the precipitation of the growing period. Most Northern, Eastern and Southern regions do not get enough rainfall for soybean cultivation. However, the precipitation patterns show a high seasonality with two rainy seasons. The long rains occur between March and June and the short rains around October, November. Accordingly, the highest suitability in Kenya occurs for March and November as starting months for soybean cultivation (Figure 3). Additionally, June as a starting month would be ideal for some Western and Coastal regions with the highest suitability class S1.

Lower mean temperatures over the growing period lead to lower suitability at altitudes higher than around 1600 m asl.

The maturation stage of soybean is most sensitive to climatic conditions. Therefore, low sunshine duration and high relative humidity during this stage can lower the suitability (e.g. relative humidity levels exceed 75% in the coastal and mountainous regions in April).

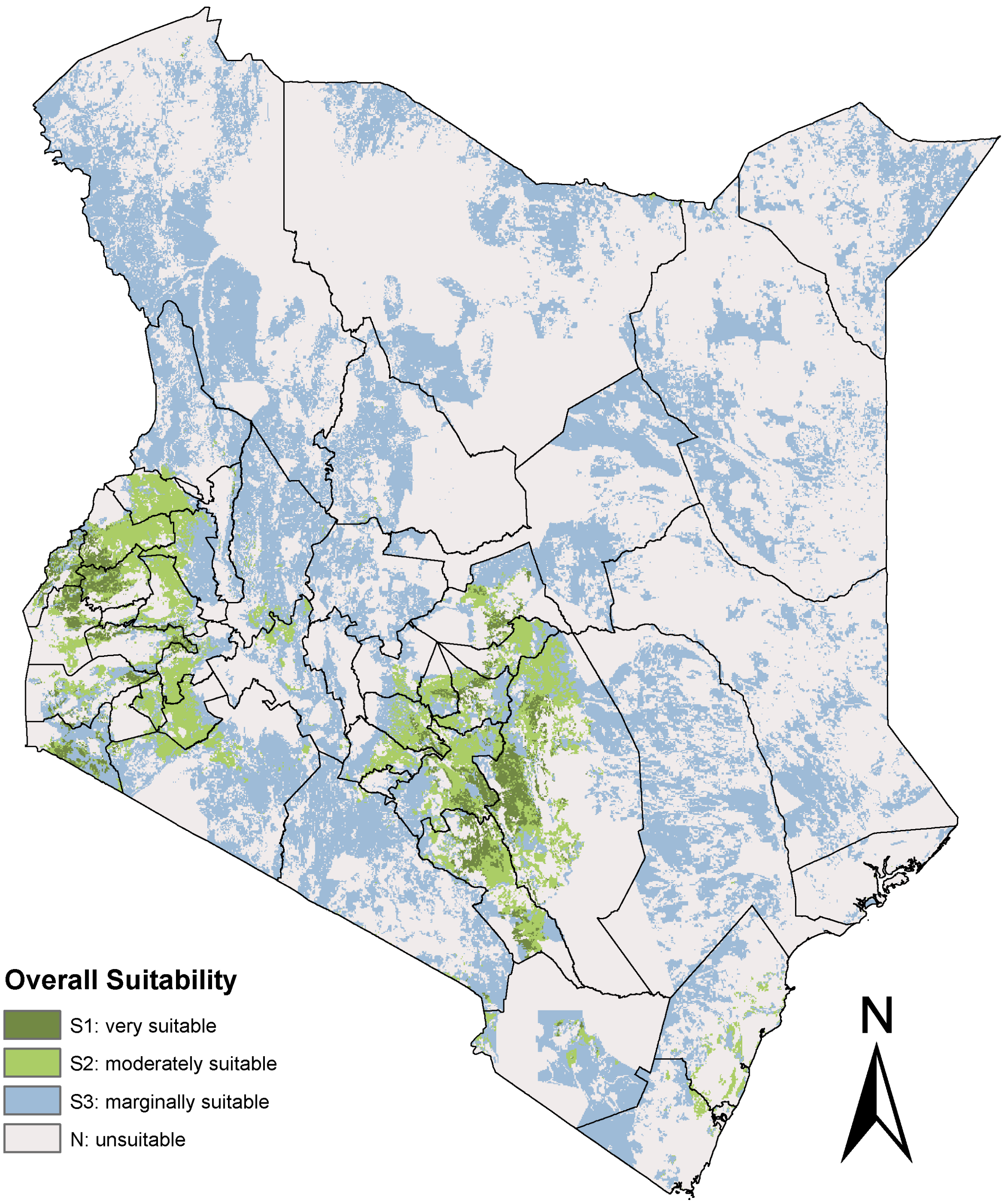


Figure 1: Overall biophysical suitability for soybean in Kenya.

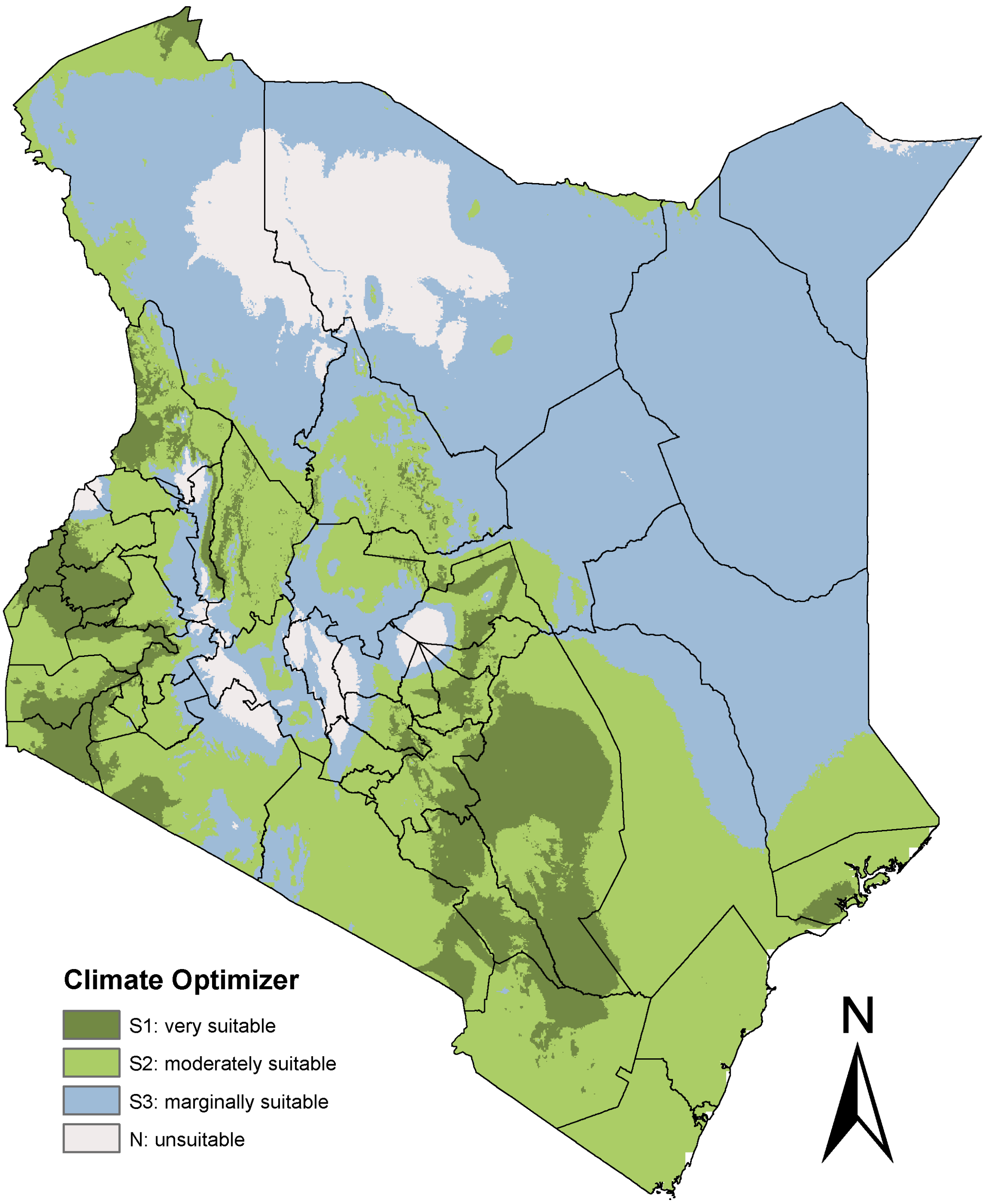


Figure 2: Overall climate suitability for soybean in Kenya based on the highest monthly suitability.

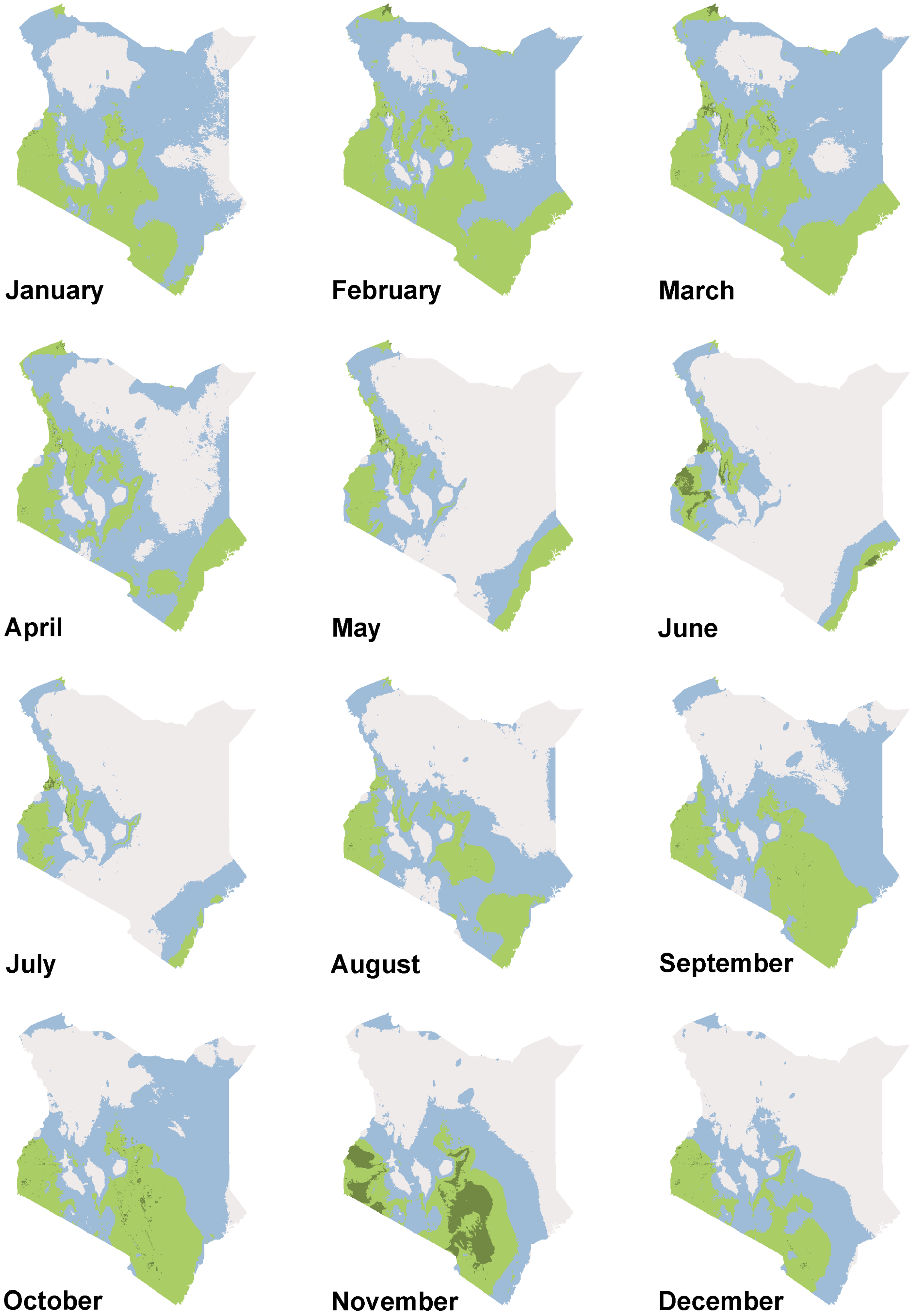


Figure 3: Climate suitability for every month as a starting month for soybean cultivation in Kenya.

3.3 Soil suitability

According to the overall soil suitability (Figure 4), the soil is highly suitable for soybean production in the main agricultural areas of Kenya.

Three of the soil parameters taken into account were found to be highly suitable for soybean cultivation without any major limitations in the agricultural areas of Kenya. This was the case for the physical characteristics soil texture and coarse fragments. Accordingly, soil salinity was not limiting the soil suitability.

The major limiting soil factors restricting the area suitable for soybean cultivation were soil depth, soil organic carbon content and soil pH. Shallow soil (Figure A1) is not only a limiting factor in most of Eastern and Northern Kenya, but also in the lower Rift Valley regions. Soil organic carbon content (Figure A2) is limiting the suitability in Eastern (except the coastal region) and Northern Kenya around Lake Turkana. Both high soil pH (Eastern, Northern and parts of Southern Kenya) and low soil pH (parts of Western and Central Kenya) strongly restricts soil suitability for soybean production (Figure A3).

Another soil parameter highly relevant for agricultural productivity is soil cation exchange capacity (CEC). Low CEC (Figure A4) could have been a further limiting factor in some Western, Central and Eastern Kenyan regions. However, due to a lack of information about the CEC requirement of soybean, this was not accounted for in the CONSUS model.

3.4 Landscape suitability

All three landscape parameters taken into account, i.e. slope, landcover and protected areas were strongly restrictive for the land suitability evaluation in certain regions of Kenya. Overall, only the regions of Western and Central Kenya and small regions along the coast remained suitable for soybean cultivation (Figure 5).

Steep slopes around the volcanic mountains of Kenya (Mount Elgon, Mount Kenya) and along the Rift Valley region impair the suitability for soybean production. In addition, high suitability was only assigned to current croplands (mainly Western and Central Kenya), while the large grasslands and shrubs covered areas were regarded as marginally suitable. Protected areas were regarded as unsuitable for conservation reasons, including some areas potentially suitable for soybean production.

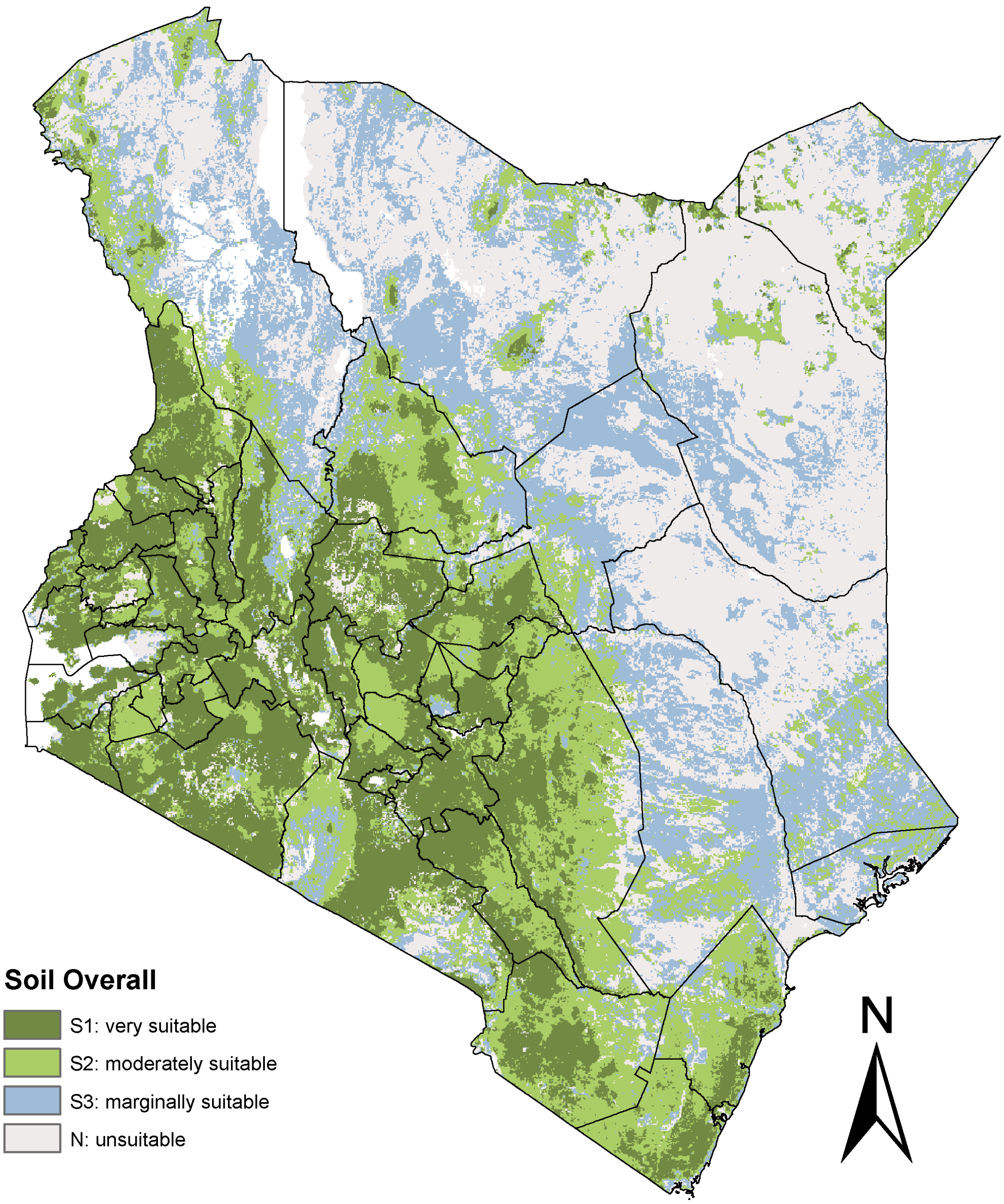


Figure 4: Overall soil suitability for soybean in Kenya.

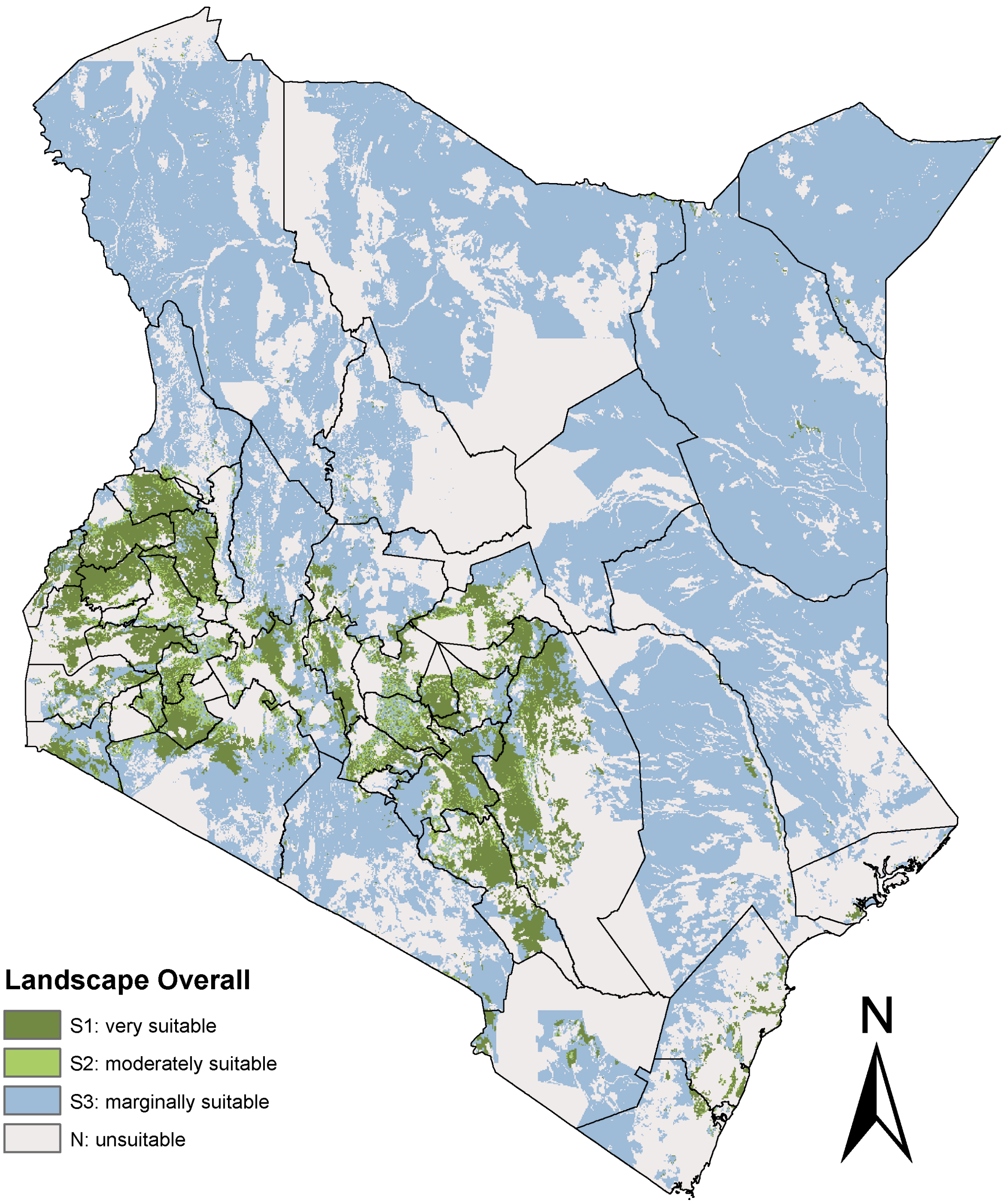


Figure 5: Overall landscape suitability for soybean in Kenya.

4 Conclusions

According to the CONSUS model, the major agricultural areas in Kenya are suitable for soybean cultivation. In these areas, soil characteristics were generally not a major limiting factor. It is much more the climate that lowers suitability at higher altitudes due to lower temperatures. Even more important is the variability of precipitation over the year. Therefore, the climate suitability shows a high seasonality with the largest suitable areas in March and November, corresponding to the two rainy seasons.

In this study, current climate conditions and general biophysical requirements of soybean were used to model their suitability in Kenya. In a next step, climate scenarios could be used to model the effect of climate change on the future suitability. Additionally, different soybean varieties specifically adapted to the local conditions could be modelled if their niche requirements are known.

Not only biophysical, but also socio-economic factors are important for a farmer's decision to grow a certain crop. We tried to integrate socio-economic indicators on a county level into our CONSUS model. However, due to limited availability of socio-economic data with a spatial dimension and due limited consistency of the existing data between the different counties, we have not discussed these factors in this report. However, socio-economic variables relevant for the adoption of soybean, such as crops currently grown, average crop or fertilizer retail prices or the average farm or household size could be further investigated.

At last, the CONSUS model shows a potential for soybean cultivation in Kenya based on the different biophysical parameters investigated. It does not give an estimate of expected yields on a plot level. It is therefore a model that can be used for prioritization in spatial agricultural planning on a regional scale. It has also not been systematically validated yet. The locations of the plots where soybean is currently grown in Kenya is not available as a spatial dataset.

5 References

Jaisli, I., Laube, P., Trachsel, S., Ochsner, P., & Schuhmacher, S. (2018). Suitability evaluation system for the production and sourcing of agricultural commodities. *Computers and Electronics in Agriculture*, 1–15. https://doi.org/10.1016/j.compag.2018.02.002

Sys, C., Van Ranst, E., Debaveye, J., Beernaert, F. (1993). Land Evaluation. Part III. Crop Requirements. Agricultural Publications No. 7, Brussels, Belgium.

6 Appendix

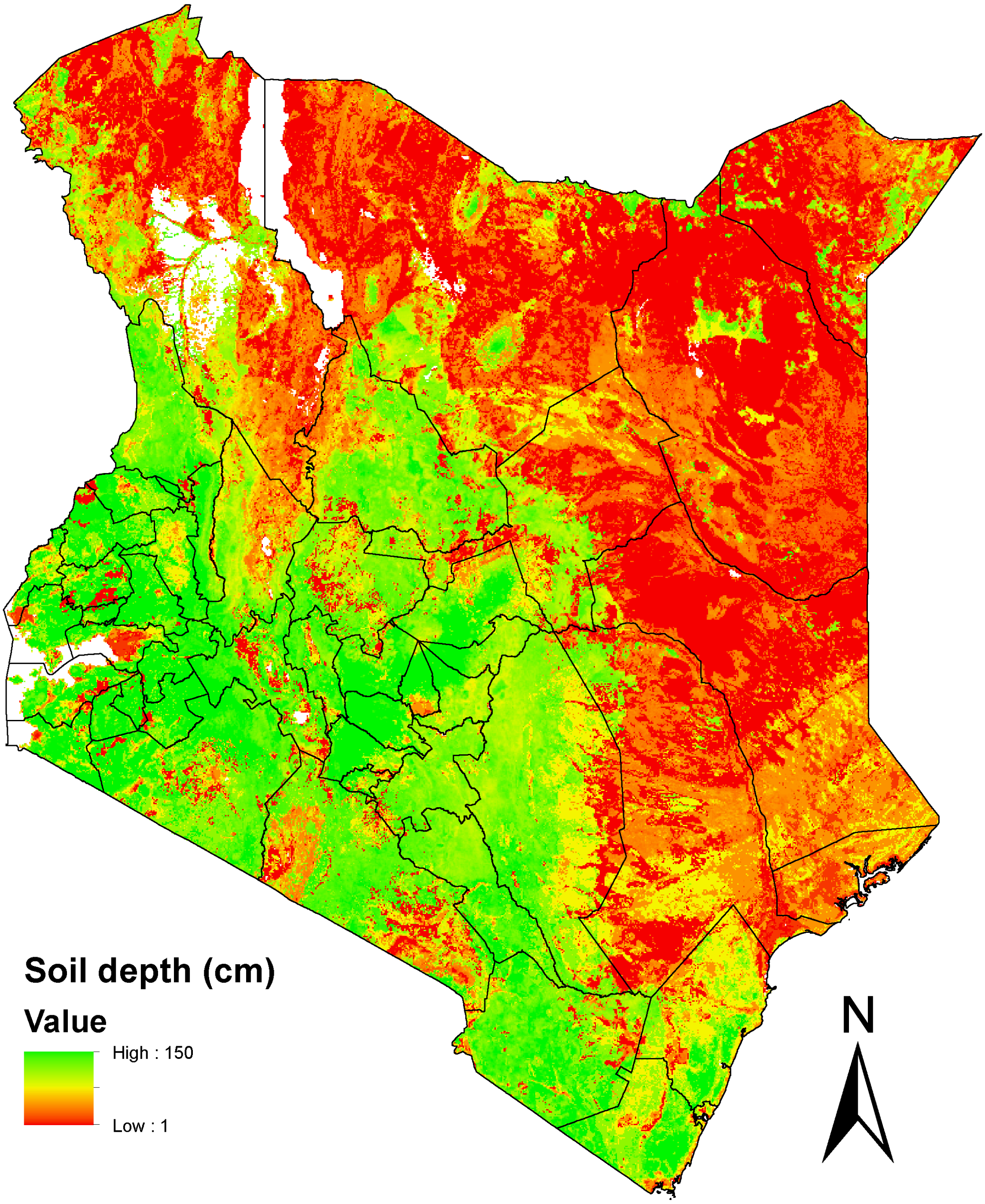


Figure A1: Map of soil depth in Kenya (data source: SoilGrids).

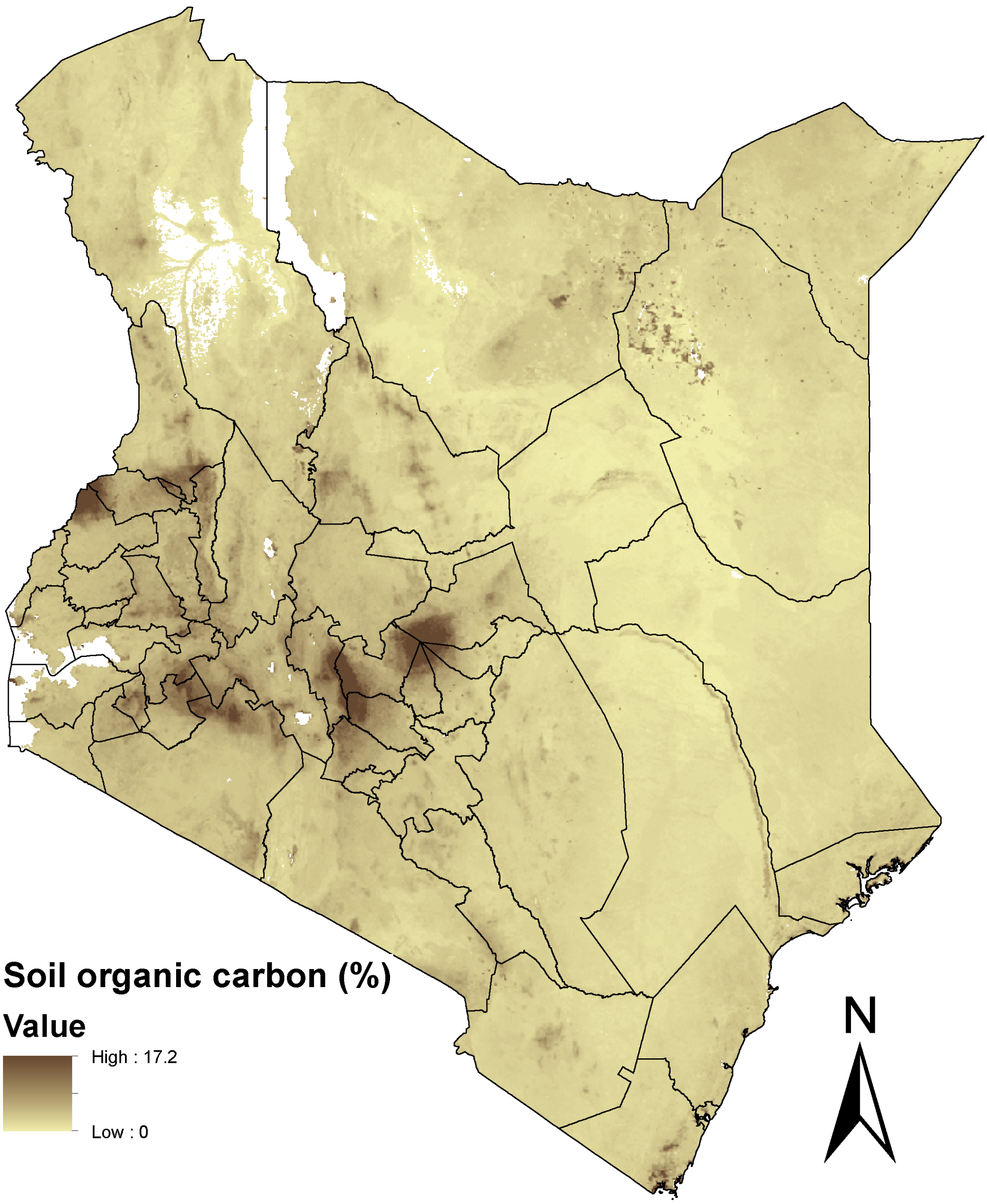


Figure A2: Map of soil organic carbon content in Kenya (data source: SoilGrids).

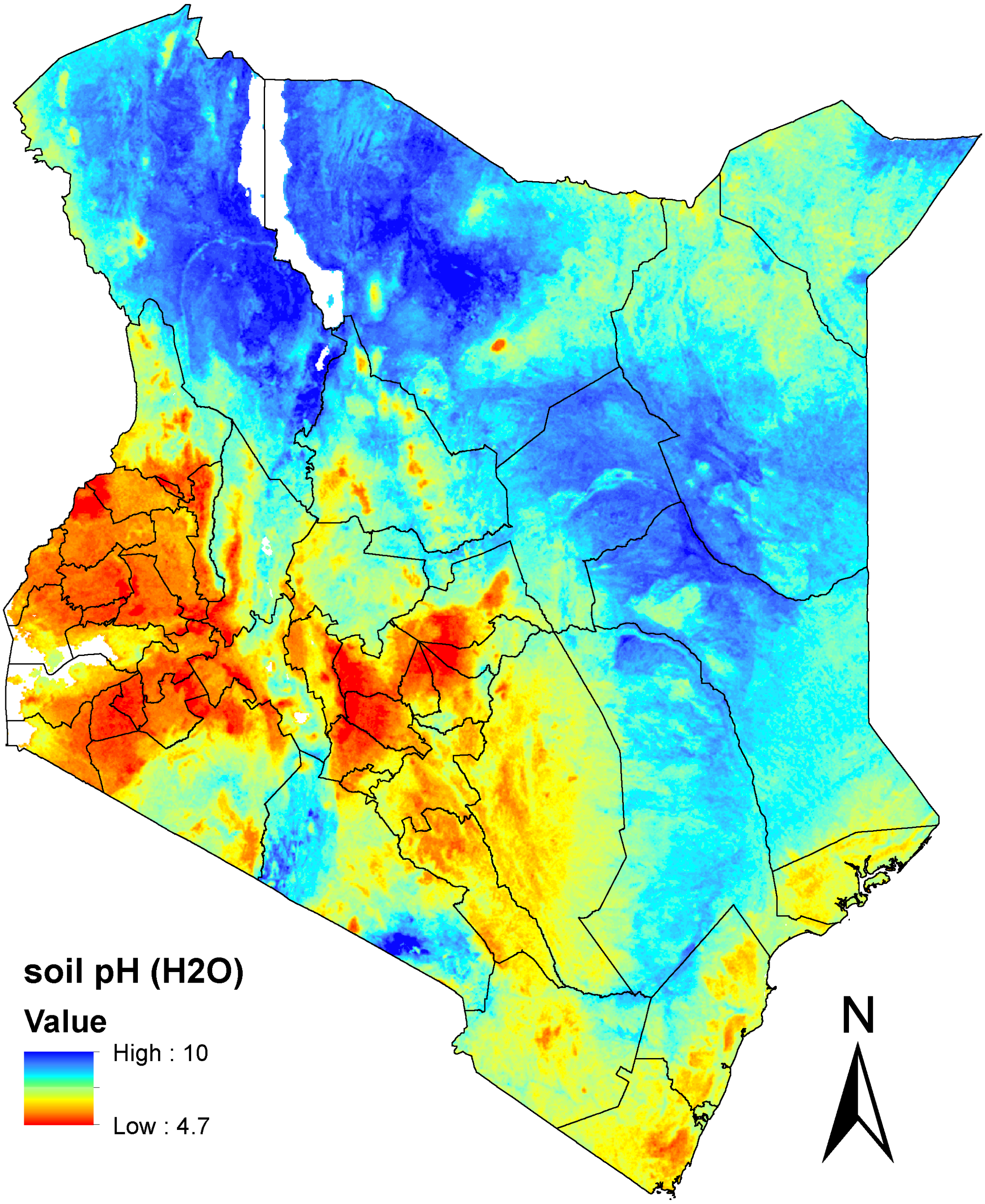


Figure A3: Map of soil pH in Kenya (data source: SoilGrids).

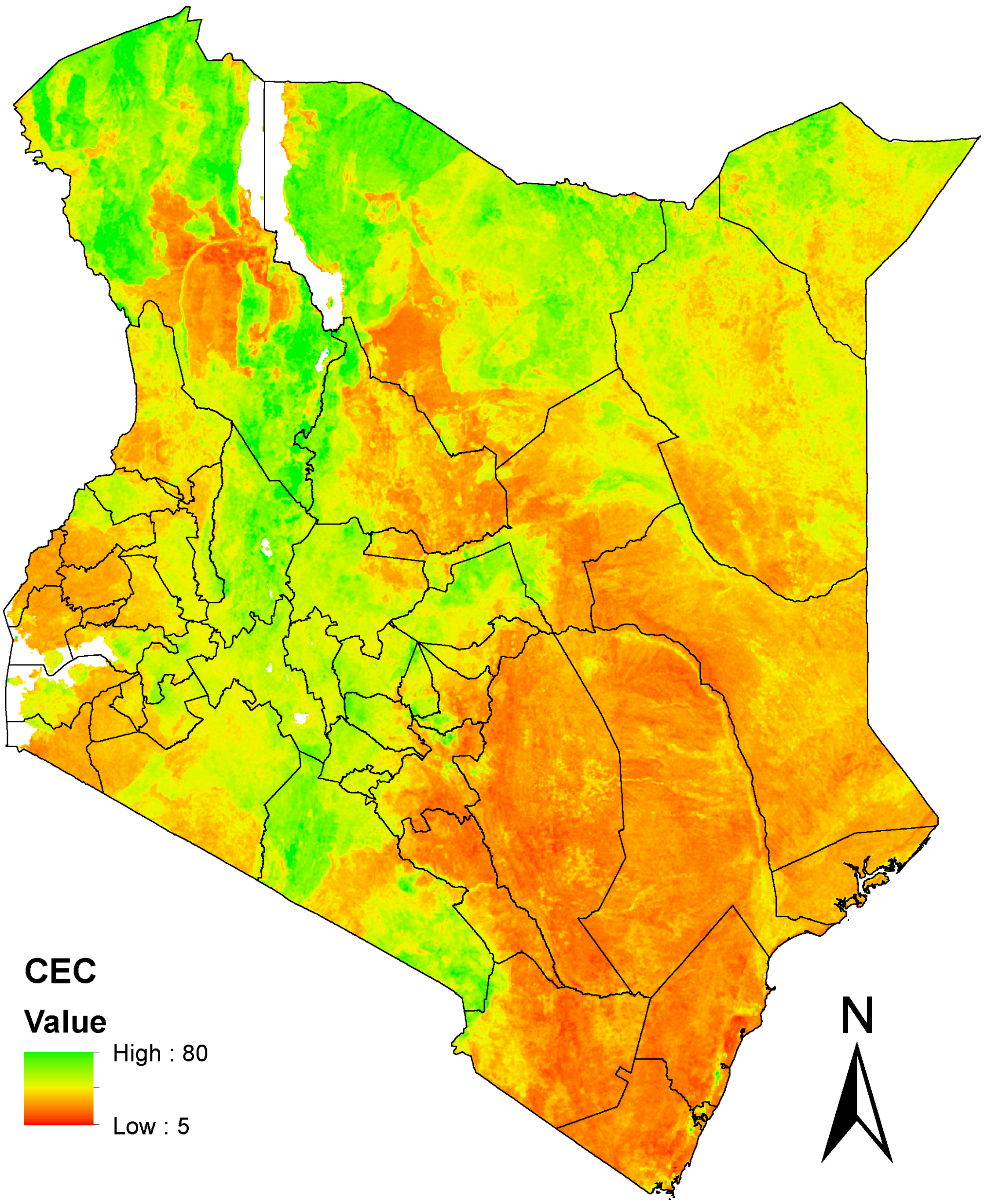


Figure A4: Map of soil cation exchange capacity (CEC in cmol(+)/kg soil) in Kenya (data source: SoilGrids).