TableS1: Soil acidification processes

Process	Reaction equation
(1)CO2 hydrolysis	$CO_2 + H_2O \rightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$
(2)Hydrolysis of nitrogen dioxide	$2NO_2 + H_2O \rightarrow HNO_3 + HNO_2 \rightarrow NO_3 + H^+$
Sulphur oxidation and hydrolysis	$S+1.5O_2+H_2O \rightarrow H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$ and $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$
(3)Soil organic matter decomposition	$[RCH_2OH] + O_2 + H_2O \leftrightarrow RCOOH \leftrightarrow RCOO^- + H^+$
(4)Nitrification of mineralized ammonium	$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$
(5)Urea hydrolysis	$CO(NH_2)_2 + 2H_2O \rightarrow (NH_4)_2CO + 4O_2 \rightarrow 2H^+ + 2NO_3^- + CO_2 + H_2O$
Ammonium sulphate	$(NH_4)_2SO_4 + 4O_2 \rightarrow 4H^+ + 2NO_3^- + SO_4^{2-} + H_2O$
Diammonium phosphate	$(NH_4)_2HPO_4 + O_2 \rightarrow 3H^+ + 2NO_3^- + H_2PO_4^- + H_2O$
(6) Root absorption of cations in excess of anions	
(7)Exchangeable aluminium formation	$3H^+ + [3O - Al - 3(OH)] \rightarrow Al^{3+} [\ ^{3-}\ ] + 3H_2O \rightarrow Al^{3+}$
(8)Al^{3+} hydrolysis	$Al^{3+} + H2O \rightarrow Al(OH)^{2+} + H^+$ and $Al(OH)^{++} + H_2O \rightarrow Al(OH)_2^+ + H^+$
(9) Root absorption of cations in excess of anions	
(10) Basic cations leaching due to high rainfall compared to evapotranspiration	
(11)Nitrate leaching due to high precipitation and available nitrate in top soil.	

TableS.2 : Descriptive statistics of soil properties for 9042 selected soil profiles in SSA cropland

Descriptive Statistics

Soil properties (1980)	Profiles	Mean	Std. D	Min	Max
Soil organic carbon (g kg^{-1})	9042	13.8	19.2	0	331.4
Soil organic matter (%)	9042	2.4	3.3	0	57.0
Total nitrogen (g kg^{-1})	9042	0.814	1.7	0	21
$CACO_3$(cmol kg^{-1})	9042	2.0	19.4	0	352
pH (water)	9042	6.0	0.9	3.6	9.3
ECEC (cmol kg^{-1})	9042	0.3	3.9	0	125
Calcium (Ca^{2+}) (cmol kg^{-1})	9042	6.9	9.5	0.02	66.9
Magnesium(Mg^{2+}) (cmol kg^{-1})	9042	2.7	3.9	0	39.6
Sodium (Na^{+}) (cmol kg^{-1})	9042	0.6	3.4	0	76
Potassium (K^{+}) (cmol kg^{-1})	9042	0.6	0.9	0	18.4
Aluminum (Al^{3+}) (cmol kg^{-1})	9042	0.2	0.6	0	13
Exchangeable acidity (Al^{3+} + H^{+})(cmol kg^{-1})	9042	0.7	3.7	0	92.5
Cations exchange capacity CEC (cmol kg^{-1})	9042	13.4	13.923	0.2	126.3
BSAT (%)	9042	71.6	27.8	1	83
CLAY (%)	9042	24.2	19.7	0	89
SILT (%)	9042	15.6	12.6	0	76
SAND (%)	9042	59.4	27.4	0	98
Soil buffering capacity (kmol (+) $ha^{-1}pH^{-1}$)	9042	58.3	46.2	4	257.4

Min : Minimum, Max : maximum, ECEC: effective cations exchange capacity,BSAT: base saturations

Table S3: Description of used scenarios

Business as Usual(BAU)	Equitable diet (EqD)	(S1)	(S2)	(S3)
Extrapolated from the trends observed during the last 42 years (1980-2022). Target in 2050 : Inorganic fertilizers will increase at the rate of 3.1% from 2012 to 2030 and 2.6% from 2030 to 2050. Crop production of staple food will increase at the rate of 0.85% from 2012 to 2050 (Alexandratos and Bruinsma, 2012)	Fertilization adjusted in each Sub Saharan African country to provide local crop production meeting requirements. Target in 2050: Actual human diets are compared to what is considered an equitable diet, which is also healthy in terms of animal protein N, i.e., a total protein ingestion of 4 kg N per capita per year with a fraction of 40% animal proteins (1.6 kg N per capita per year). N fertilizer will increase with 22% from 2022 to 2050 and crop production of staple food will increase with 3.5% (Elrys et al., 2020)	+20% EqD	-20% EqD	-40% EqD

S1 : Scenario 1 (20% Increase IFN* input of EqD), S2 : Scenario 2 (20% decrease IFN* input of EqD), S3 : Scenario 3 (40% decrease of IFN* input of EqD) and INF : Inorganic fertilizer Nitrogen

Table S4: **Element concentrations in crop harvest, crop residues and related parameters in crop removal calculation**

crops	Element concentration in harvested part [a] g/kg							Element concentration in crop residues [a] g/kg							Removal factor
	N	P	K	Ca	Mg	Na	S	N	P	K	Ca	Mg	Na	S	all nutrients
Rice	11.8	1.1	1.03	0.13	0.34	0.04	0.3	9.1	1.3	18.9	6.1	2.2	0.12	1.38	20
Wheat	19	3.25	2.89	0.34	0.04	0.07	0.9	6.5	0.8	10.5	5.2	1.6	0.29	0.96	60
Maize	13.9	2.18	3	0.14	0.96	0.03	0.83	9.2	1.5	11.8	5.4	2.2	0.39	0.94	75
Sorghum	16.6	3.29	2.81	0.22	1.29	0.06	1.0	12	1.4	14.3	4.6	1.9	0.39	0.94	70
Millet	14.4	2.29	2.84	0.41	1.07	0.04	2.01	8.2	1.0	17.5	4.7	4.5	0.3	1.06	75
Irish potato	4.4	1.3	6.9	0.08	0.23	0.03	0.26	2.3	0.7	4.5	3	5.8	1.0	3.7	20
Sweet Potato	4.8	0.8	7.3	0.24	0.15	0.43	0.26	2.1	1.2	3.3	21	4.6	1.0	3.0	95
Soybean	56	4.65	15	1.91	1.99	0.02	0.3	18	1.9	11.7	17	4.8	1.0	2.1	75
Peanut	38.4	3.24	5.87	0.39	1.78	0.04	1.7	18	1.6	10.9	17	5.6	1.0	1.4	60
Vegetables	1.74	0.79	1.48	0.29	0.14	0.32	0.32	29	3.7	27.7	14	4.9	0.0	3.2	95
Other tubers	4.6	0.3	2.9	0.24	0.23	0.03	0.26	1.9	0.5	3.1	3	5.8	1.0	3.7	40
Other pulses	20	3.4	11	0.22	1.29	0.06	1.0	10	1	1	4.6	1.9	0.39	0.94	50

Other pulses: peas and beans; other tubers: yam.(FAO, 2004)

Table S5: Environmental covariates description

Acronym	Description	Dataset source
WCL_BIO01	Mean annual temperature	
WCL_BIO02	Mean diurnal range	
WCL_BIO03	Isothermality	
WCL_BIO04	Temperature seasonality	
WCL_BIO05	Max temperature of warmest month	
WCL_BIO06	Min temperature of coldest month	
WCL_BIO07	Temperature annual range	
WCL_BIO08	Mean temperature of wettest quarter	
WCL_BIO09	Mean temperature of driest quarter	Historical and future climate data were downloaded on world climate website
WCL_BIO10	Mean temperature of warmest quarter	https://www.worldclim.org using the "raster" package and getData function (1kmx1km)
WCL_BIO11	Mean temperature of coldest quarter	
WCL_BIO12	Annual precipitation	
WCL_BIO13	Precipitation of wettest month	
WCL_BIO14	Precipitation of driest month	
WCL_BIO15	Precipitation seasonality	
WCL_BIO16	Precipitation of wettest quarter	
WCL_BIO17	Precipitation of driest quarter	
WCL_BIO18	Precipitation of warmest quarter	
WCL_BIO19	Precipitation of coldest quarter	
Basic_cations	Basic cations	(Hengl et al., 2015)(https://data.isric.org)
Blk	Bulk density	(Hengl et al., 2015)(https://data.isric.org)
CEC	Cation exchange capacity	(Hengl et al., 2015)(https://data.isric.org)
CLAY	Clay	(Hengl et al., 2015)(https://data.isric.org)
DEM	Digital elevation model	Downloaded (https://earthexplorer.usgs.gov)
CWR	Crop water requirement (ET)	Global Potential Evapotranspiration Database(Zomer et al., 2022)
ExcAcidity	Exchangeable acidity	(Hengl et al., 2015)(https://data.isric.org)
Lith	Parent material (Lithology)	Global Lithological Map Database(Hartmann and Moosdorf, 2012)
OC	Total soil carbon	(Hengl et al., 2015)(https://data.isric.org)
SAND	sand particles	(Hengl et al., 2015)(https://data.isric.org)
SILT	Silt particles	(Hengl et al., 2015)(https://data.isric.org)
Slope	DEM derivative	Spatial analysis in ArcMap10
Curvature	DEM derivative	Spatial analysis in ArcMap10
TWI	Total wetness index (DEM derivative)	Spatial analysis in ArcMap10
N fertilizers	Predicted by this study using	

Max: Maximum, Min: Minimum

Table S6 : Cross validation for single preditive mode () and ensemble model for both sol pH decline and soil pH

Cross validation results for soil pH decline prediction in SSA cropland																		
	2022			BAU			EqD			S1			S2			S3		
Base models	RMSE	MAE	R^2	RMSE	MAE	R^2	RMSE	MAE	R^2	RMSE	MAE	R^2	RMSE	MAE	R^2	RMSE	MAE	R^2
xdbDART	0.04	0.01	0.89	0.04	0.02	0.90	0.08	0.04	0.90	0.04	0.02	0.92	0.09	0.04	0.98	0.06	0.03	0.98
rf	0.035	0.01	0.93	0.03	0.02	0.92	0.07	0.03	0.91	0.05	0.02	0.93	0.08	0.03	0.98	0.07	0.03	0.98
Ensembled	0.02	0.01	0.95	0.03	0.01	0.94	0.07	0.03	0.93	0.08	0.01	0.92	0.04	0.01	0.94	0.04	0.01	0.94
Cross validation results for soil pH prediction 1980-2050																		
	2022			BAU			EqD			S1			S2			S3		
	RMSE	MAE	R^2	RMSE	MAE	R^2	RMSE	MAE	R^2	RMSE	MAE	R^2	RMSE	MAE	R^2	RMSE	MAE	R^2
xdbDART	0.55	0.4	0.62	0.6	0.4	0.6	0.57	0.41	0.64	0.58	0.42	0.65	0.57	0.4	0.63	0.56	0.39	0.6
rf	0.54	0.37	0.64	0.56	0.38	0.61	0.55	0.39	0.65	0.58	0.4	0.66	0.54	0.37	0.65	0.55	0.38	0.61
Ensembled	0.53	0.37	0.64	0.54	0.38	0.63	0.54	0.37	0.66	0.56	0.39	0.66	0.55	0.38	0.63	0.54	0.37	0.62

RMSE: root mean squared error, MAE: mean absolute error and R^2 : coefficient of determination,the plot of observed and predicted soil pH decline and soil pH showed that observed and predicted values were concentrated on 1:1 lines (see Fig S3)

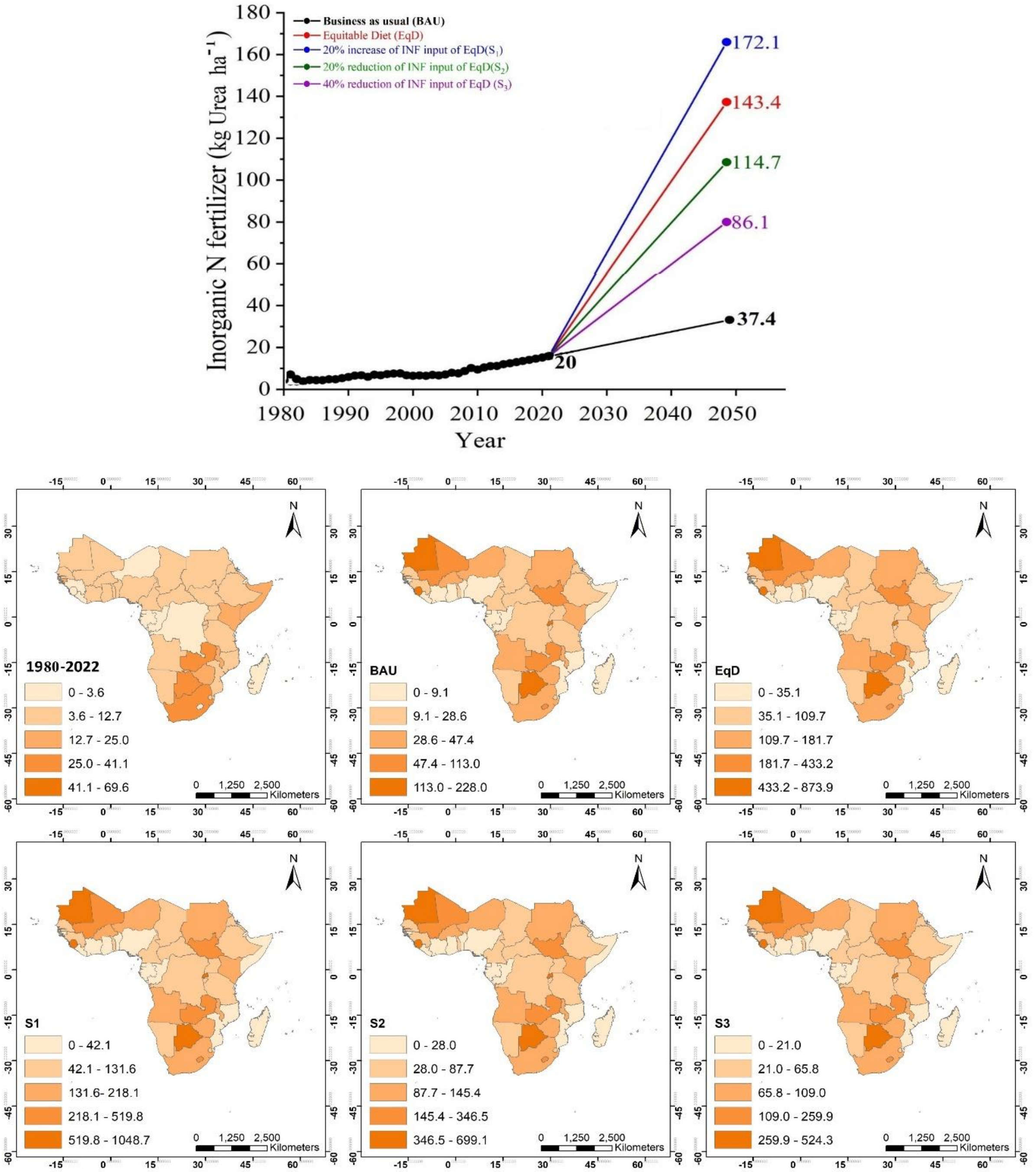

Figure S1. Urea fertilizer use in SSA africa (1980-2050)Spatial variation of N fertilizers application in SSA cropland following different scenarios , Business as usual (BAU), Equitable Diet (EqD), Increase of 20% of INF needed by EqD (S1), Reducing 20% of INF needed by EqD and decreasing 40% of INF needed by EqD scenario.

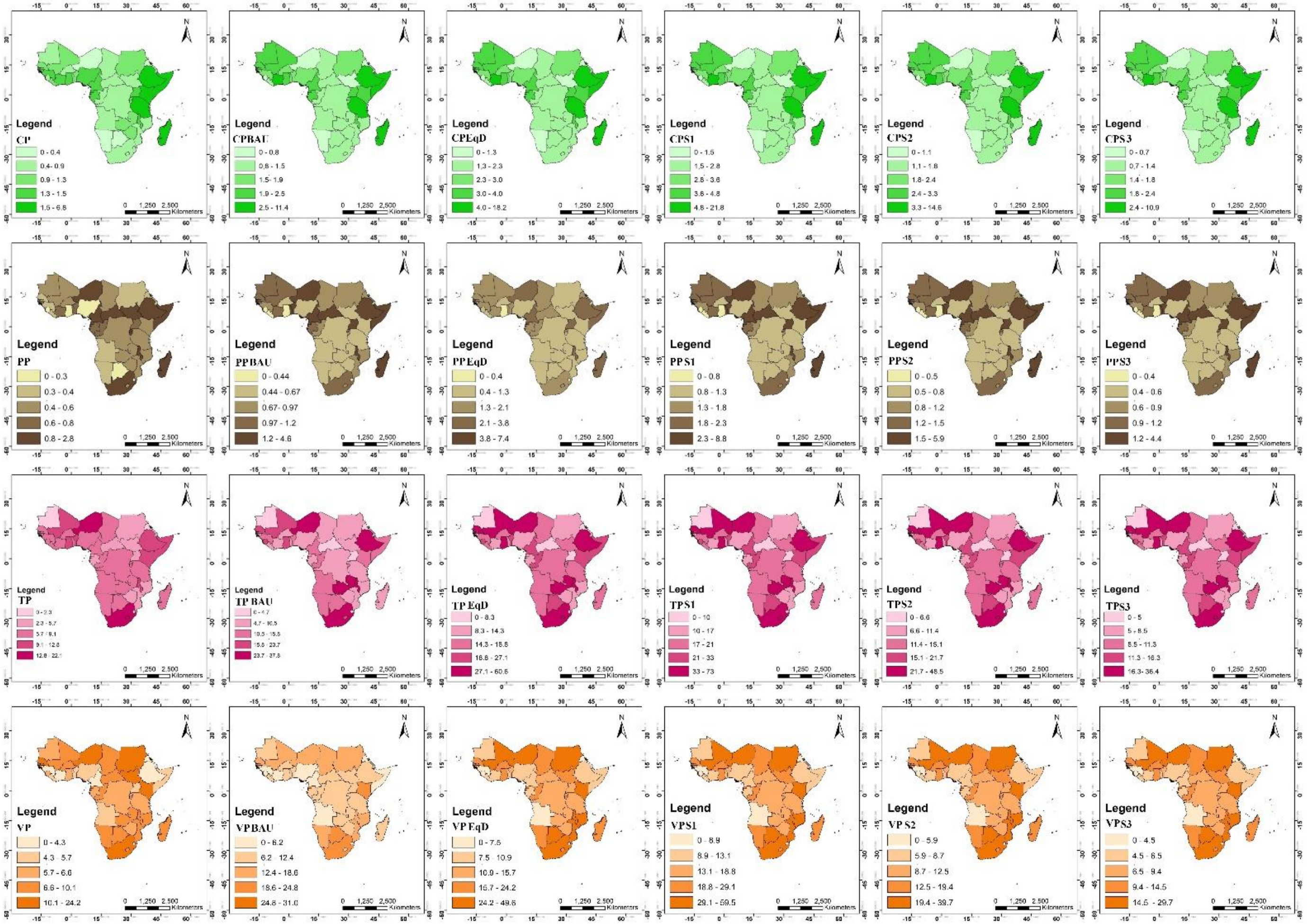

Figure S2 : Spatial and temporal variation of crop production of different cropping system : Spatiatial and temporal distribution of staple food production in SSA countries (1980-2050), Crop production is expressed in Mg ha^{-1} yr^{-1} and Cereals (CP), Pulses(PP), Tubers production (TP) and Vegetable production (VP) following different scenarios. BAU, EqD, S1, S2 and S3 represent business as usual, Equitble diet, S1, S2 and S3 scenarios.

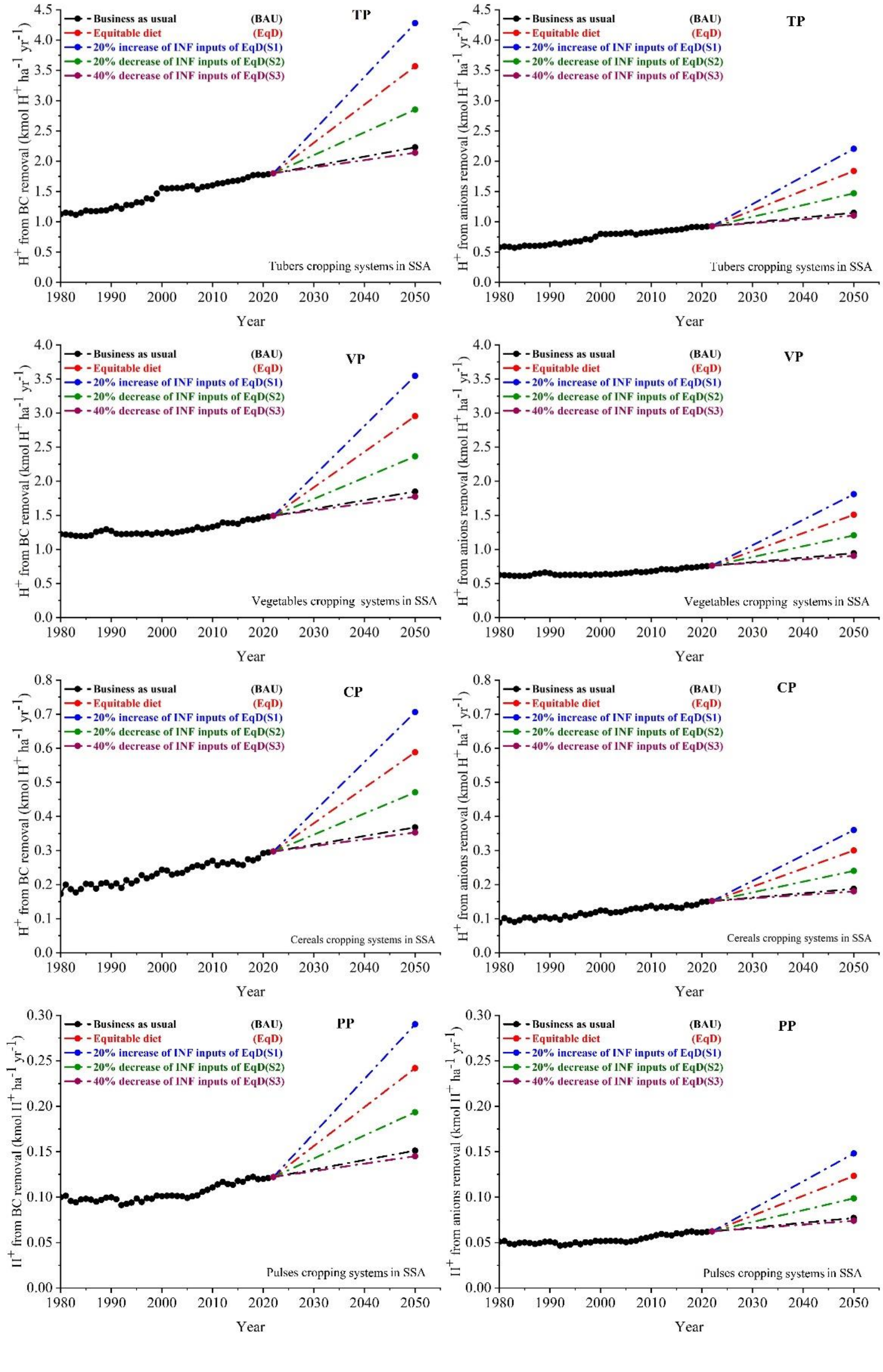

Figure S3: Contribution of yield and crop residues on protons production under different scenarios

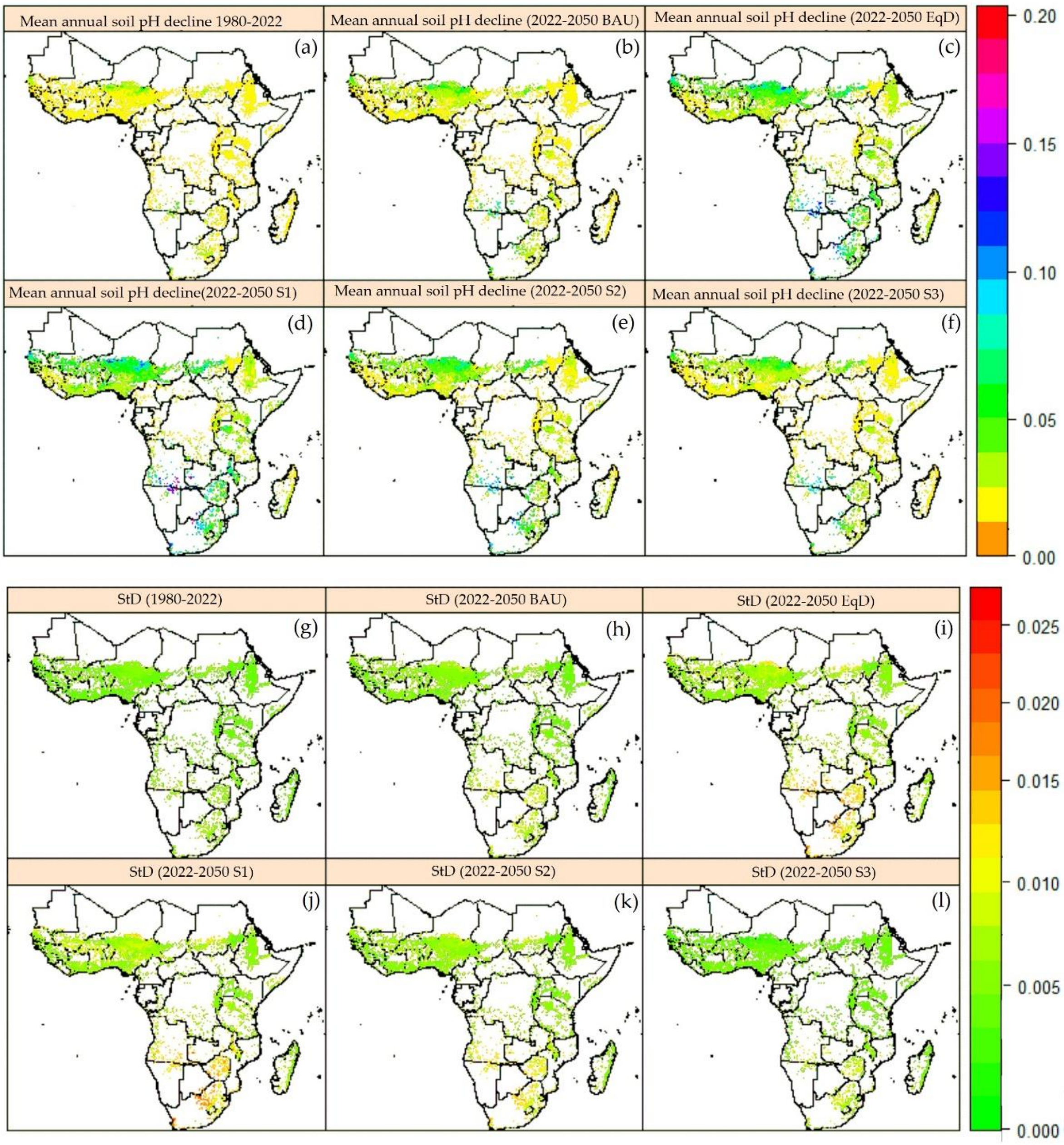

Figure S4: All predicted maps of soil pH decline and their uncertainties

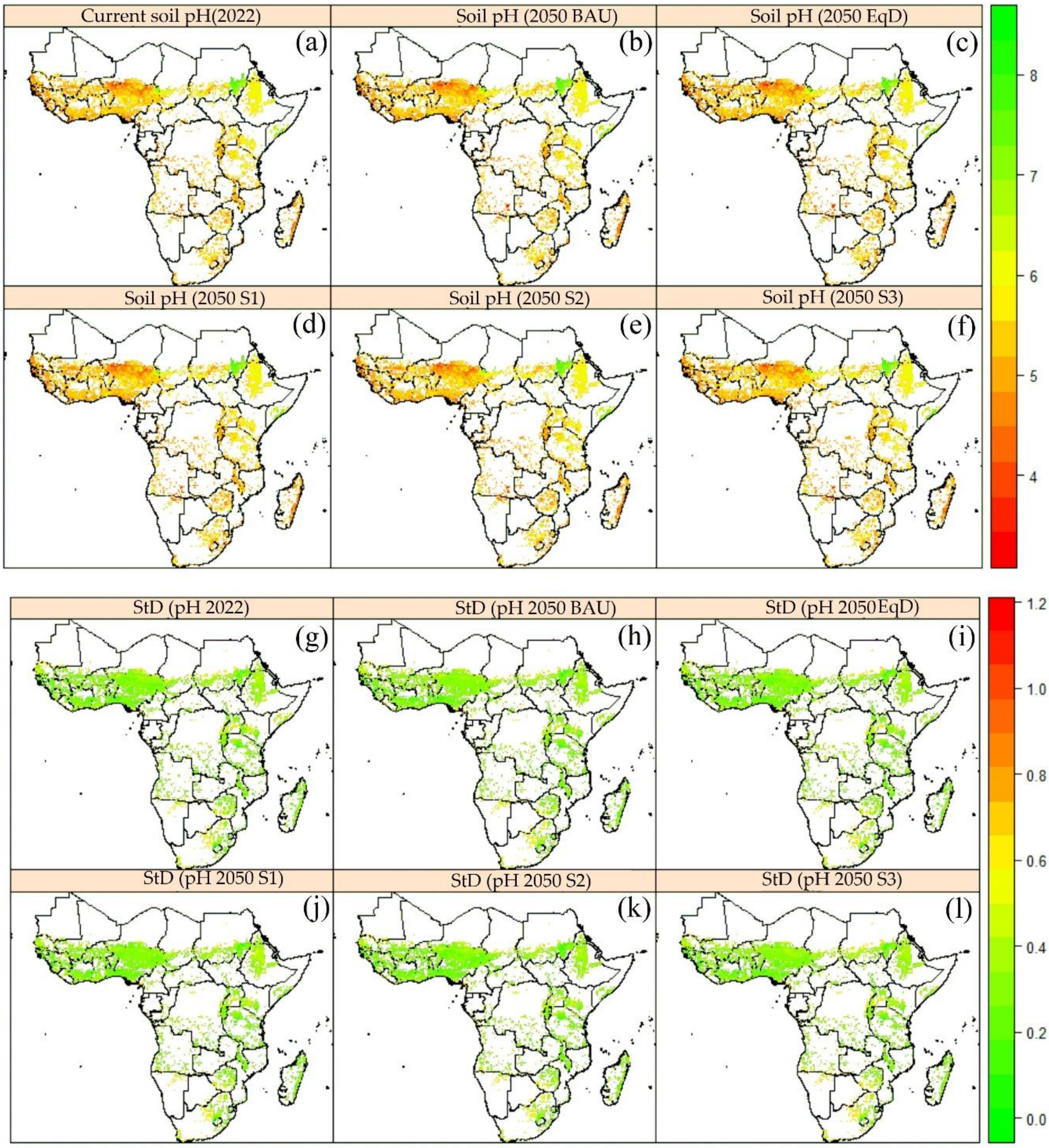

Figure S5: Predicted change of soil pH (all scenarios) and their uncertainties

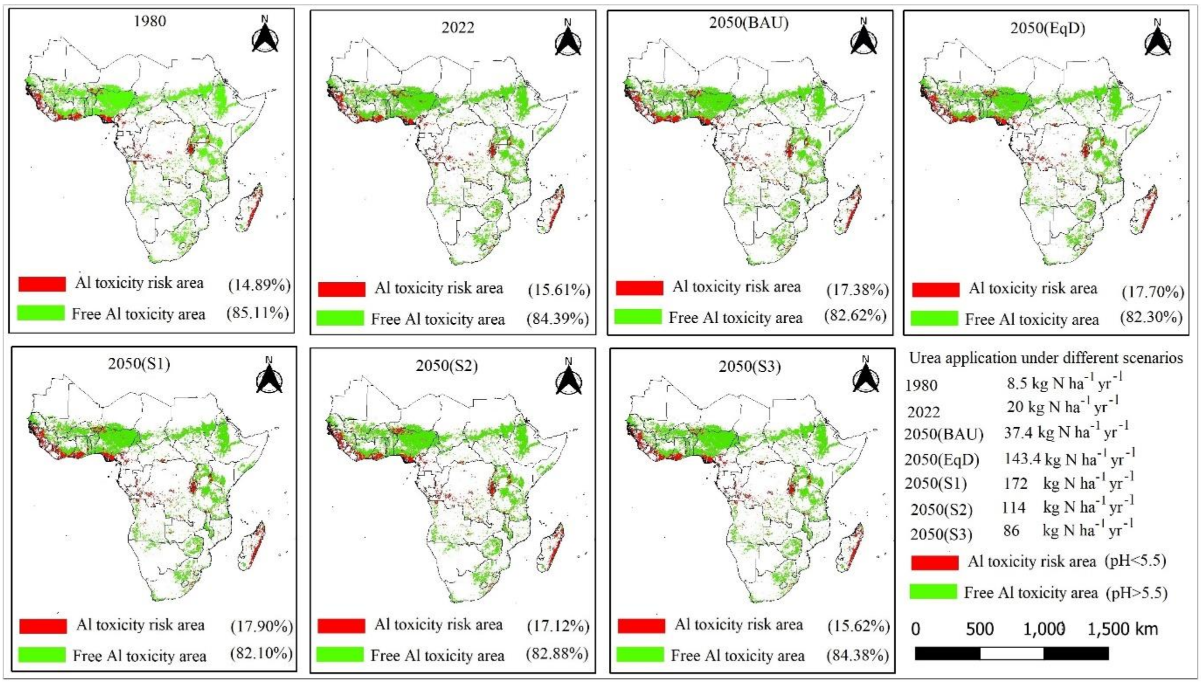

Figure S6: Spetio-temporal change of Aluminium toxicity under different scenarios (1980-2050)

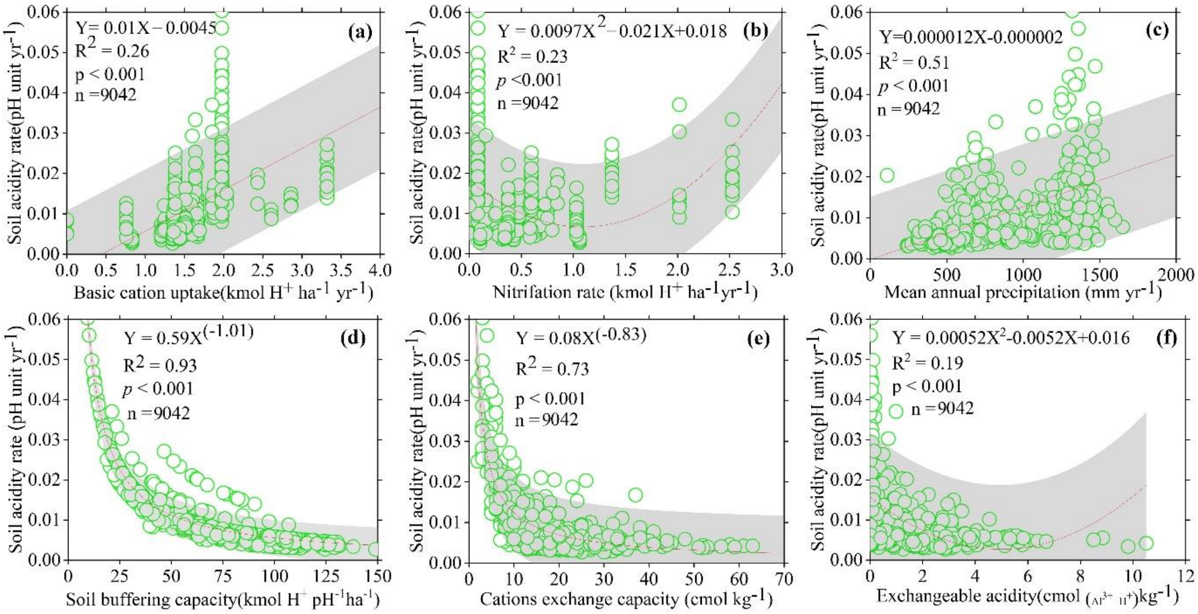

Figure S7: Relationship of soil pH decline with soil properties