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Global Soil Organic Carbon Sequestration Potential Map

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GLOBAL SOIL
PARTNERSHIP

Argentina: Soil Organic Carbon Sequestration Potential National Map.

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*Franco Daniel Frolla[1]***,** *Marcos Esteban Angelini[2], Marcelo Javier Beltrán[3], Guillermo Ezequiel Peralta[5], Luciano Elias Di Paolo[4], Darío Martín Rodríguez[2], Guillermo Andrés Schulz[2], Carla Pascale Medina[6]*

[1]INTA Bordenave - frolla.franco@inta.gob.ar

[2]INTA, Soil Institute - angelini.marcos@inta.gob.ar

[3]INTA, Soil Institute - beltran.marcelo@inta.gob.ar

[4] Global Soil Partnership Secretariat - FAO - lucianoeliasdipaolo@gmail.com

[5] Global Soil Partnership Secretariat - FAO - Guillermo.Peralta@fao.org

[6] Global Soil Partnership - Argentinian National Focal Point - Carla Pascale Medina - cpasca@magyp.gob.ar

INTA

Ministerio de Agricultura, Ganadería y Pesca
Argentina

Executive summary

In the last decade's agricultural land increased and soil organic carbon (SOC) stocks decayed in Argentina. Several farming practices may be used to restore or diminish the SOC loss and different SOC simulation models have been used to estimate and project SOC changes. However, these studies have mainly focused on specific regions and practices. The goal of this work was to apply the FAO-GSP Technical Specifications and Country Guidelines for Global Sequestration Potential Map v1.0 approach to produce a SOC potential sequestration map for Argentina at 1 km resolution using the best available national data. Specific objectives were 1) to estimate the SOC evolution under the business as usual (BAU) practices in twenty years (2040), 2) to estimate the absolute SOC sequestration of different sustainable soil management scenarios: 5% (SSM1), 10% (SSM2) and 20% (SSM3) increment in organic matter inputs, and 3) to calculate the differences in SOC sequestration between the BAU scenario and SSM scenarios (relative sequestration rates - RSR), as well as the differences between SSM scenarios in 2040 and the SOC stocks in 2020 (absolute sequestration rates - ASR). The results showed that average SOC sequestration in the BAU scenario would decrease at a rate of -0.089 t C ha^{-1} year^{-1} between 2020 and 2040. SSM1 and SSM2 projections also showed a negative SOC evolution. Only SSM3 generated absolute SOC increments. With respect to the BAU scenario, we found an average increment of 0.025 t C ha^{-1} yr^{-1} for SSM1, an increase of 0.053 t C ha^{-1} yr^{-1} for SSM2, and an increase of 0.106 t C ha^{-1} yr^{-1} for SSM3, for the period under study. Our results suggest that agricultural systems are currently a source of CO_2 rather than a net sink at the national level, and that increasing C inputs by 5 to 10% would not be enough to achieve a positive C balance in the future. Nevertheless a sequestration potential of 4.2 to 16.7 Mt C yr^{-1} can be expected under SSM compared to BAU practices, indicating that the wide adoption of SSM practices could mitigate about 11-48% of current annual national agricultural emissions.

Abbreviations

C - Carbon

CO_2 - Carbon dioxide

SOC - Soil organic carbon

BAU - Business as usual

SSM - Sustainable soil management

RSR - Relative sequestration rate

ASR - Absolute sequestration rate

1. Introduction

Soil organic carbon (SOC) is a key factor affecting soil physical fertility, as it improves several soil properties such as infiltration, structural stability, porosity, aeration and structure. It also improves soil chemical fertility since C is part of the soil organic matter, which constitutes the main reservoir of nutrients for crops (nitrogen, sulfur, zinc, among others). SOC is positively correlated with soil microbial biomass that acts on nutrient cycling and metabolization processes of toxic molecules.

The total SOC stock in topsoil (0-30cm) is about 19.7 Pg C (FAO-ITPS GSOC map, 2018). Thus, due to the size of the soil carbon pool, even small increments in the net soil C storage may represent a substantial C sink potential. Although agricultural greenhouse gas emissions (GHGs) contribute to an important share of Argentina GHG emissions (135.53 $MtCO_2eq$, 37% of total country GHG emissions; SAyDS, 2019), increasing ASOC stocks through judicious land use and sustainable soil management (SSM) practices may represent an important strategy to reduce and mitigate GHG emissions.

In Argentina, the total productive area is about 157 million hectares (INDEC, 2021). Agricultural area (croplands) is about 40 (forty) million hectares, predominantly under no tillage system (91% agricultural area; AAPRESID, 2020). Soybean is the main product (45 million tons in 17 million hectares), followed by corn (44 million tons in 6.3 million hectares), wheat (17 million tons in 6.5 million hectares), barley (4.1 million tons in 0.1 million hectares) and sunflower (2.7 million tons in 1.3 million hectares).The rest of the area (over 124 Million hectares) is occupied with grasslands and shrublands dedicated to livestock production, and other agricultural uses.

In the last decade's agricultural land increased and SOC content decayed. This process of land use change was explained by increasing soybean monoculture and displacing livestock area, reducing SOC content (Lavado & Taboada, 2009). There has been an intense expansion of agriculture at the expense of grasslands, native forests and other natural resources in semiarid, sub-humid and subtropical regions of the country (Volante et al., 2012). Currently, soils of the Chaco-Pampean region exhibit SOC levels between 40-70% of the contents of virgin soils (Alvarez & Steinbach, 2009; Sainz Rozas et al., 2011; Milesi Delaye et al., 2013).

Several farming practices may be used to restore or diminish the SOC loss, reduce soil erosion, sequester atmospheric carbon dioxide (CO_2) and improve the soil quality (Poffenbarger et al., 2020). Among these practices, the inclusion of cover crops (CC) during winter has been postulated as one of the most promising activities (Ruis & Blanco-Canqui, 2017). The inclusion of CC showed average SOC sequestration rates of 0.45 tC/ha/yr (± 0.03), in Argentina (Alvarez et al., 2017; Beltran et al., 2018; Romaniuk et al., 2018). Increasing nutrient availability, crop growth and residue returns by increasing fertilizer use showed an increment of SOC around 0.18 tC/ha/yr (± 0.03) (Duval et al., 2020; Restovich et al., 2019). The inclusion of cycles with perennial pastures in crop rotations showed average SOC sequestration rates of 0.76 tC/ha/yr (± 0.03), exhibiting the greatest potential to increase SOC stocks (Costantini et al., 2016; Gil et al., 2016).

Sustainable soil management (SSM) practices (FAO, 2020) such as the above mentioned practices have demonstrated potential to increase SOC stocks in different agricultural systems in Argentina, and thus sequester atmospheric CO_2 as SOC to mitigate GHG emissions. However, SOC sequestration from these practices show highly variable sequestration rates, depending on edapho-climatic conditions, land use and management, among other factors. It is therefore relevant to identify which regions, soils, climates and systems have a greater potential to increase SOC stocks, in order to establish priorities for research and implementation of private and public policies. In this sense, the use of SOC models has shown in other countries and regions to be a powerful tool to identify these conditions (Lugato et al., 2014).

In Argentina, different SOC simulation models have been used to estimate and project SOC changes. The IPCC (Intergovernmental Panel on Climate Change) empiric Tier 1 and Tier 2 approaches have been applied to estimate historic SOC stocks and flows in the Pampa Region at a county scale (Villarino et al., 2014). The AMG model (Andriulo et al., 1999) has been one of the most widely used, especially in agricultural lands of the Rolling Pampa Region , to project SOC stocks under different management scenarios (Irizar et al., 2015). The Century model has also been adjusted and used to simulate historic SOC changes in temperate grasslands (Piñeiro et al., 2006). Finally, the RothC model has also been adjusted and used to simulate SOC stocks under continuous cropping and mixed systems (Studdert et al., 2011; Montiel et al., 2019). However, these studies have mainly focused on specific regions, edapho-climatic conditions and practices. Coupling SOC dynamic models with empirical models and spatial data, such as soil data and climatic data, will enable the transition from site-specific SOC stocks estimations to spatial predictions and projections, and this in turn become a valuable tool to better identify conditions with higher potential to increase SOC stocks, as well as to detect hot-spots of SOC losses.

During the previous year, FAO (2020) developed an approach to simulate SOC stocks and generate SOC sequestration potential national maps, using a spatialized version of the RothC model and georeferenced input data. The goal of this work is to apply the FAO (2020) approach to produce a SOC potential sequestration map for Argentina at 1 km resolution using the best available national data. The objective of the national SOC sequestration map is (1) to estimate the SOC evolution with the business as usual practices; (2) the absolute SOC sequestration of different sustainable soil management scenarios (3) the differences in SOC sequestration between the business as usual and sustainable management scenarios. The National Institute of Agricultural Technology (INTA) is the institution in charge of this process.

2. Methods

2.1. Study area

Argentina is in southern South America with a total surface area of 2.8 million km^2. According to the country's total area, it is ranked the seventh among all world countries. Argentina's climatic characteristics are very diverse because of its vast territory, with a wide range of rainfall, from 2000 mm in the northeast to 200 mm in the south region of the country. The temperature varies from a mean annual temperature of 24° C in the north to less than 5° C in the south region (Bianchi & Cravero, 2010; Rodríguez & de la Casa, 1990).

With almost 40 million hectares of grain sown per year and more than 40 million heads of cattle, Argentina is a large net exporter of agricultural products such as soybean, wheat, corn, sunflower, sorghum, beef and milk.

Argentinian orography is characterized by the large range system named Cordillera de los Andes in the western part of the country, while the east is characterized by large flat plains interrupted by small mountain systems. The climate, soil types, vegetation and orography, determines an important variation in SOC stocks (0-30 cm), that range between 1.1 t C ha^{-1} and 255.7 t C ha^{-1} (FAO and ITPS, 2018). The total SOC stock of Argentina is 19.7 Pg.

Regarding the predominant soil classes (Fig. 1a), the regions of Argentina have different soil types. In the Pampas and Chaco Region, located in the center-eastern and center-northern part of the country, Mollisols and Alfisols are predominant; in the north-east region, the region between the big rivers of Argentina (Paraná and Uruguay Rivers), Vertisols, Alfisols and Mollisols are the predominant soil orders, while in the northeastern area of this region there are Alfisols and Ultisols; Alfisols, Entisols and Aridisols can be found to the north-western part of the country, under an arid climate; in the certern-wester region (Cuyo Region), also under an arid climate, Entisols are predominant; finally, in the Patagonia Region, with a predominant cold arid climate, Aridisols are the predominant soil order.

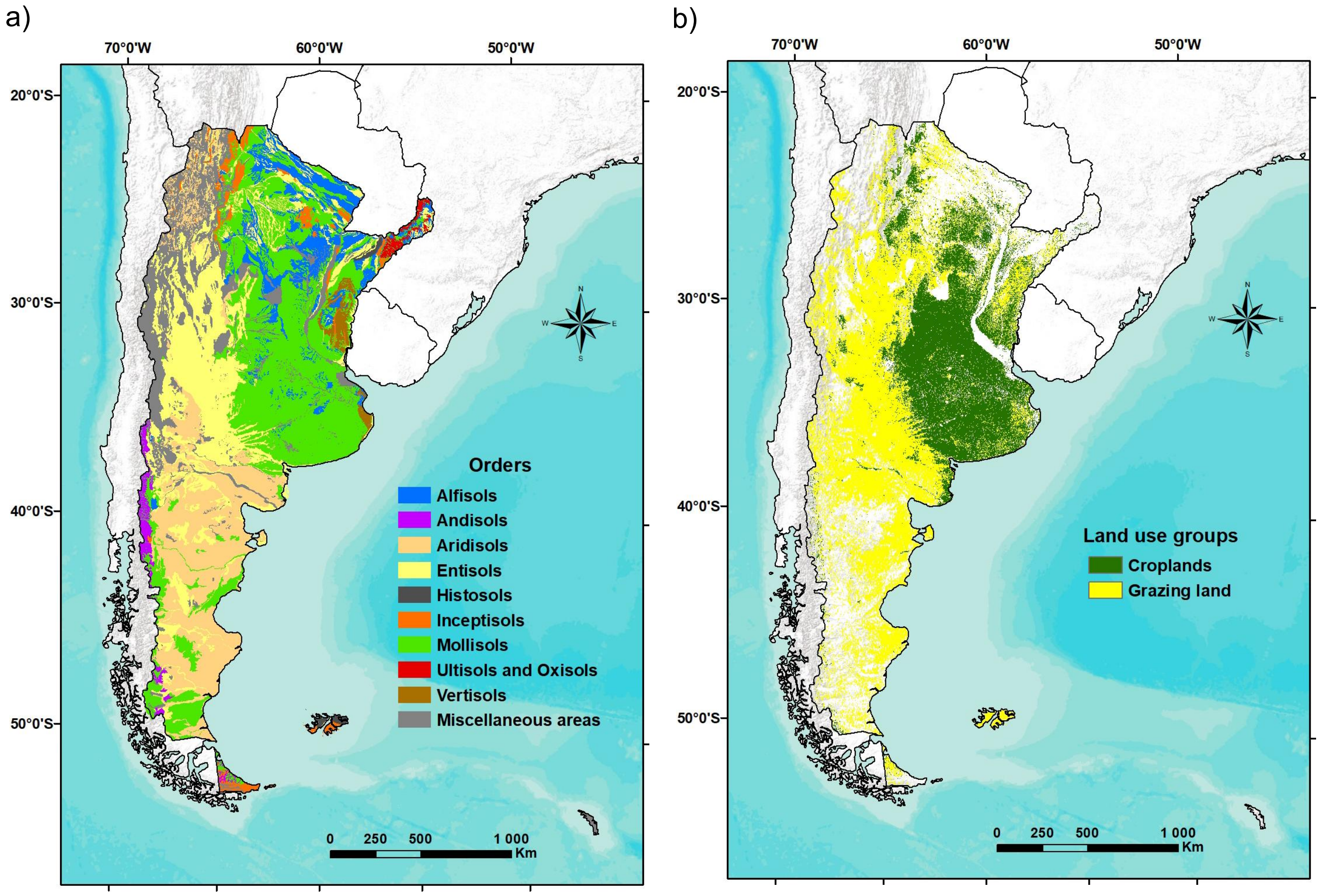

Figure 1. a) Dominant soils orders of Argentina (adapted from Rodríguez *et al.*, 2019); b) Land use groups used for modelling purposes.

According to the Guidelines for Global Sequestration Potential Map v1.0 (http://www.fao.org/3/cb0353en/CB0353EN.pdf), two groups of land uses were selected as the target areas of this work, Croplands and Grazing lands (Fig. 1b). These areas were obtained from the ESA land cover map (ESA, 2017), where category 2 was taken as Croplands and categories 3 and 5 were taken as Grazing lands. The first category has a predominance of annual crops associated with mixed crop-livestock systems and improved sown pastures (649 691 km^2), covering 23% of the Argentinian area. The category Grazing lands has mostly cattle production in grasslands, shrublands and native pastures (1 021 911 km^2), which represents 37% of the Argentinian area.

2.2. General Methodology

We applied the methodology proposed at the FAO-GSP Technical Specifications and Country Guidelines for Global Sequestration Potential Map v1.0. The methodology consisted of applying the RothC model (Coleman & Jenkinson, 1996) for estimating the SOC stock after 20 years (2020 - 2040) under different soil management scenarios. We predicted SOC stock in 2040 under the current soil management (business as usual - BAU) and under the three standard SSM scenarios where sustainable soil management (SSM) practices are applied with different organic matter inputs, 5% increase (SSM1), 10% increase (SSM2) and 20% increase (SSM3). We estimated the differences between SOC stock in 2020 and SOC stocks in 2040 under BAU and SSM scenarios (absolute difference maps), and the difference between SOC stocks in 2040 under the BAU and SSM scenarios (relative difference maps). The model was applied at point locations where land use belonged to cropland and grazing lands categories (see 2.3., input data layers).

The model was run in three phases: (1) an equilibrium run of 500 years, (2) a short spin-up of 20 years, and (3) a forward run of 20 years. In the first step RothC must run iteratively to equilibrium to estimate SOC pools (decomposable plant material-DPM; resistant plant material-RPM; microbial biomass-BIO; and humified organic matter-HUM) considering an initial arbitrary C input of 1 $tC.ha^{-1}$. The equilibrium was reached after 500 years assuming constant environmental conditions (derived from climate conditions in the 1980-2000 period), clay content and a representative land use (taken from year 2000). The C inputs were optimised to fit the current SOC stock. Argentina GSOC map was mainly generated using historic legacy data generated before year 2000, so the spin up phase was run up to that year.A short spin-up ("warm up") phase was run as a temporal harmonization in SOC stocks between 2000-2020, and to include the effects of climatic conditions from 2000-2020. In the third step, the SOC stocks were estimated between 2020-2040, under four conditions, one of them is assuming the same constant optimised C input (BAU), and the other three are assuming the SSM strategies with the abovementioned increases in C inputs.

All the processing was done in R (R core team, 2021). The work was organised in two main R scripts where specific routines were organised in functions. Given the large computational required for each location, the country was divided into twelve sub areas that were processed consecutively. Each of the three steps of the RothC model were applied in parallel within each subarea in a RStudio server with 24 CPU and 144 GB of RAM memory (Intel(R) Xeon(R) CPU, X5675, 3.07GHz) of the CIDETIC group at the National University of Lujan (https://cidetic.unlu.edu.ar/en/recursos/). The complete process was completed after four days of computational work. Also, the work was carried out under version control of the script using GitHub (https://github.com/INTA-Suelos/ArgSOCseq).

2.3. Input data layers

The input variables required were SOC stock at 0-30 cm, clay content in percentage, annual mean precipitation, temperature and evapotranspiration, and land use 2000-2020. We used the 1-km national SOC stock map at 0-30 cm in tons C ha^{-1}, and its uncertainty map expresend in standard deviation, which have been contributed to the GSP-GSOC map (FAO and ITPS, 2018) as the baseline SOC stock for the year 2000. National clay content map expressed in percentage and its uncertainty map were also produced at 1 km resolution following a digital soil mapping approach (publication in preparation). The climatic layers were taken from Terraclimate (http://www.climatologylab.org/terraclimate.html) global data source at ~4-km (1/24th degree) spatial resolution. We used the 1980-2000 and 2001-2020 periods. The layers units were in mm for precipitation and evapotranspiration and celsius degrees for temperature. Land use layers were not available for different years at national scale, therefore the ESA land cover maps were used at 300 m resolution (ESA, 2017). ESA land cover classes were reclassified into the FAO classes following the default procedure from the Guidelines for Global Sequestration Potential Map v1.0 (http://www.fao.org/3/cb0353en/CB0353EN.pdf). Monthly vegetation cover was estimated using the provided Google Earth script from MODIS 1km NDVI products.

2.4 Model/s performance evaluation

We used already published data from long term field experiments where the RothC model was evaluated under croplands and mixed crop-pasture systems, and compared to the observed SOC stocks (Studdert *et al*., 2011; Montiel *et al*., 2019). These included field trials in the Southeastern area of the Pampa Region. We also obtained field SOC data from long term field experiments where different crop and cover crop rotations were evaluated (Agosti *et al*., 2020) in the Northern region of the Buenos Aires province and Southern area of Santa Fe province (from 2011-2020). Using the information from crop residue inputs, SOC stocks, monthly climate data (temperature, rain, evapotranspiration) from near meteorological stations, and clay content of the 0-30 cm, we simulated SOC stocks during the period using the RothC model, and compared observed vs. simulated results during the analysed period. The dataset included a total of 400 SOC measurements. Simple least square linear regression analyses of observed (average of experimental replications) on simulated values were performed. The equality of the intercept and of the slope of the regression line to zero and one, respectively, was tested through F-tests. Root mean squared error (RMSE, TC ha) and percentage of the observed mean were calculated to evaluate general model performance (Smith & Smith, 2007).

2.5. Uncertainty

In order to give an uncertainty estimation, we used the layers of the standard deviation of the prediction of SOC stock and clay percentage. Then, we estimated the 95% prediction intervals for both input layers and ran the models using the maximum and minimum values of SOC stock and clay. For each scenario map, we produced an uncertainty map of one standard deviation expressed in percentage with regards to the predicted value of each scenario.

3. Results

3.1. Summary and spatial prediction of SOC sequestration rates in Argentina

Table 1 shows that the ASR in the BAU scenario showed a decrease of -1.78 ± 2.36 t C ha^{-1} (Fig 1) in 20 years from 2020 to 2040 (-0.089 t C ha^{-1} year^{-1}). SSM1 and SSM2 projections also showed a negative SOC evolution, -0.061 t C ha^{-1} year^{-1} and -0.034 t C ha^{-1} year^{-1} respectively. The SSM3 scenario, instead, showed a positive absolute SOC sequestration, being higher for croplands (0.046 t C ha^{-1} year^{-1}) than Grazing lands (-0.01 t C ha^{-1} year^{-1}), with a higher variability in croplands (Fig 4). With regards to the relative SOC sequestration (RSR), the results showed a positive rate for the three scenarios with respect to the BAU situation. In 20 years, the SOC stock increased on average by 0.52 t C ha^{-1} for SSM1, 1.06 t C ha^{-1} for SSM2 and 2.12 t C ha^{-1} for SSM3. The higher SOC sequestration rate was obtained in SSM3 (0.106 t C ha^{-1} yr^{-1}), followed by SSM2 (0.053 t C ha^{-1} yr^{-1}) and SSM1 (0.025 t C ha-1 yr-1).

Table 1: Average absolute sequestration rate (ASR) and relative sequestration rate (RSR) for each SMM scenario and land use group.

		Average ASR			Average RSR		
	Area	SSM1	SSM2	SSM3	SSM1	SSM2	SSM3
	Km2	t C ha^{-1} yr^{-1}			t C ha^{-1} yr^{-1}		
Croplands	649 691	-0.048	-0.016	0.046	0.032	0.064	0.128
Grazing Lands	1 021 911	-0.073	-0.052	-0.01	0.02	0.042	0.083
Average all land uses	1 671 602	-0.061	-0.034	0.018	0.026	0.053	0.106

Tabla 2: Total SOC sequestration for each SMM scenario and land use group

		Total absolute sequestration			Total relative sequestration		
	Area	SSM1	SSM2	SSM3	SSM1	SSM2	SSM3
	Km2	Mt C yr^{-1}			Mt C yr^{-1}		
Croplands	649 691	-2.90	-0.99	3.00	2.08	4.17	8.34
Grazing Lands	1 021 911	-7.26	-5.18	-0.98	2.09	4.18	8.35
Total Sum	1 671 602	-10.1	-6.08	2.02	4.2	8.29	16.7

Table 2 shows the total absolute and relative SOC sequestration for each land use group and at national scale. It can be seen that the only positive absolute SOC sequestration can be achieved in the Croplands under a SSM3. Fig. 4 shows that SSM scenarios are less variable in grazing lands than in croplands (Fig. 5). Fig. 4 shows that the ASR is mostly negative in all grazing lands, while it is more variable under croplands, suggesting that there are many areas that can reach a positive rate in any of the SSM scenarios (Fig. 5). It can also be seen in these figures that RSR is always positive, meaning that any SSM practice can improve the current condition (BAU).

The highest relative SOC sequestration rates were obtained in the Pampas region, decreasing from West to East and from North to South. The areas that presented the highest losses of C in the BAU scenario (Fig 2) also presented the highest relative sequestration rates of C with respect to the SSM situations (Fig 3). We found that the maps of Fig. 2 show a prominent decrease of SOC in the center-east of the country, with a limit that goes from south-east to north-east in Buenos Aires Province. This pattern is also present in Entre Rios province. We analysed the causes of this pattern and found that it is highly correlated to the potential evapotranspiration of december (R^2 = 0.50) and the monthly mean precipitations of May (R^2 = 0.66), June (R^2 = 0.46) and July (R^2 = 0.45).

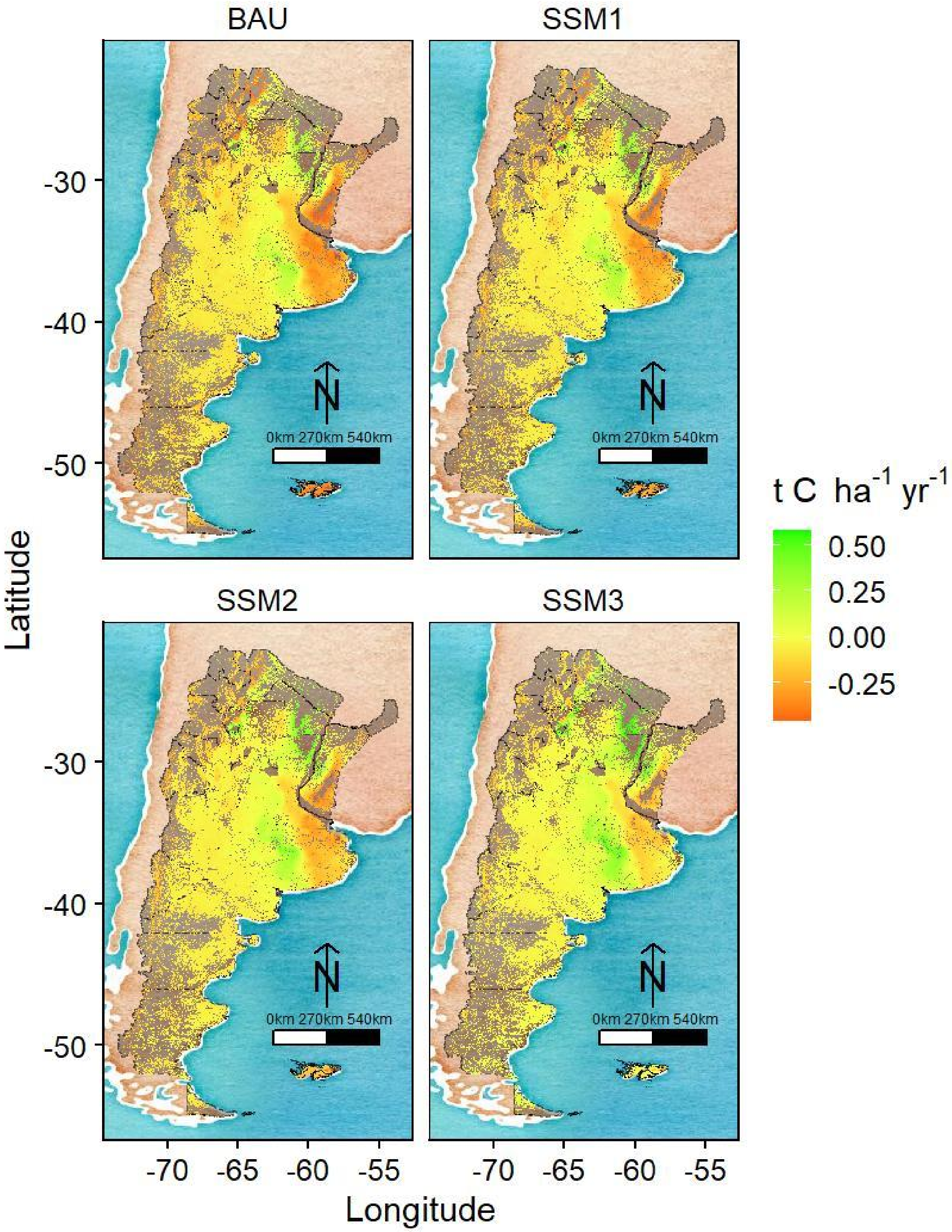

Figure 2. Absolute SOC sequestration rates (ASR). Business as usual (BAU) model and the three hypothetical scenarios of SOC gains from the adoption of a sustainable soil management strategy.

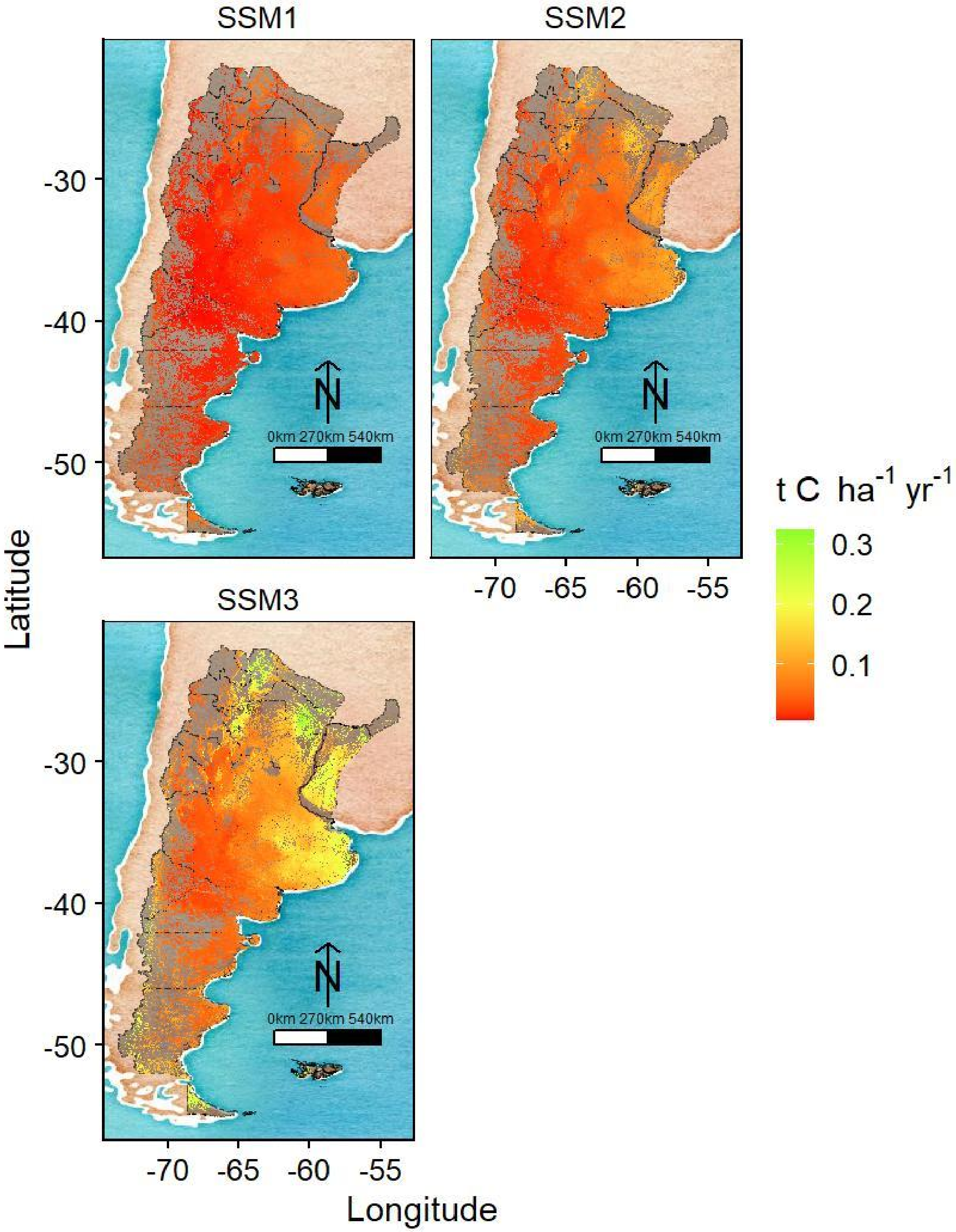

Figure 3. Relative sequestration rates (RSR) in the three hypothetical scenarios of SOC gains from the adoption of a sustainable soil management strategy.

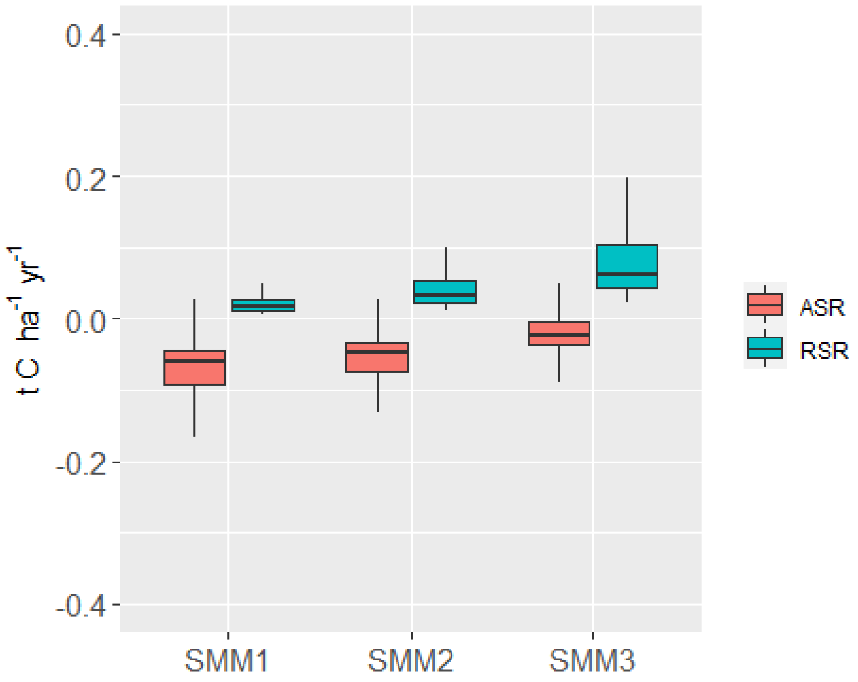

Figure 4. Absolute SOC sequestration rates (red) and relative SOC sequestration rates (blue) in the Grazing Lands of Argentina

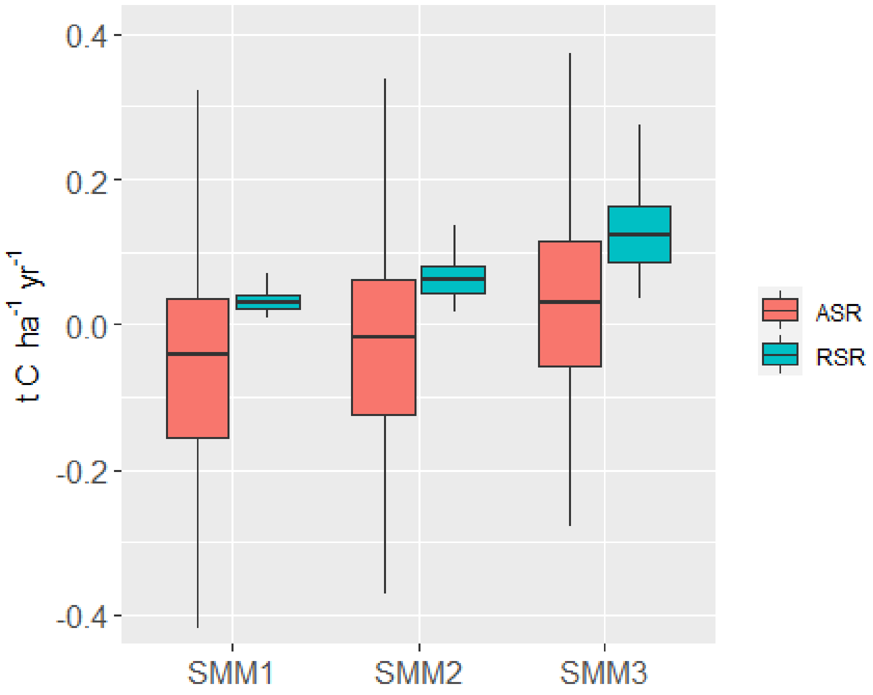

Figure 5. Absolute SOC sequestration rates (red) and relative SOC sequestration rates (blue) in the Crop Lands of Argentina

3.2. Model performance evaluation

Linear regressions of observed SOC stocks from field data vs. simulated SOC stocks with the RothC model (Fig. 5) were highly significant ($P < 0.0001$), with a 0.86 R^2. The root mean square error of the whole dataset was 5.69%. Assuming that absolute values of RMSE not exceeding 5.0% are acceptable (Smith and Smith, 2007), considering all datasets, overall performance of the model was near the acceptable range. RMSE values were generally similar when considering the datasets independently (5.65 % for the Agosti et al., 2020 dataset , and 5.15% in Studdert et al., 2011), except the Montiel et al. (2019) dataset which showed greater RMSE values (6.87%). The regression line was below the 1:1 line at lower SOC stocks (<75 t C.ha-1), indicating that RothC tended to overestimate SOC stocks for these conditions (Fig. 5). On the contrary, RothC tended to underestimate results at higher SOC stocks.

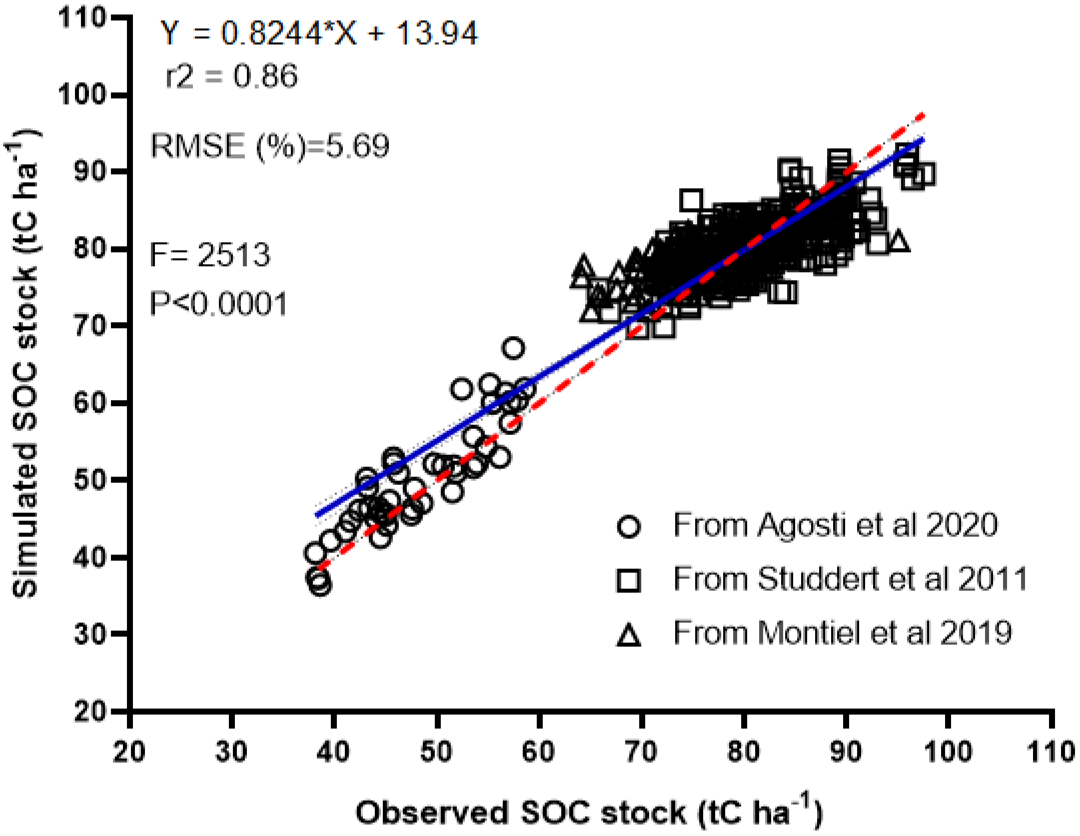

Figure 6. Observed vs. simulated SOC stocks in field experiments in croplands from the Pampa Region of Argentina, where the RothC model was evaluated. The blue line represents the linear regression, the red dotted line represents the 1:1 relation. Root mean square error (RMSE), correlation coefficient (r^2) and P value of the regression are also shown. For details of each experiment refer to Studdert et al., (2011), Montiel et al., (2019), and Agosti et al., (2020).

3.3. Uncertainties

The mean uncertainty estimated for ASR at 68% prediction interval was 47% ± 20%, while it was 45% ± 17% for RSR. Note that those areas with a negative lower limit of the prediction intervals for SOC and/or clay were converted to missing value (NA), which reduced the areas of some of the products.

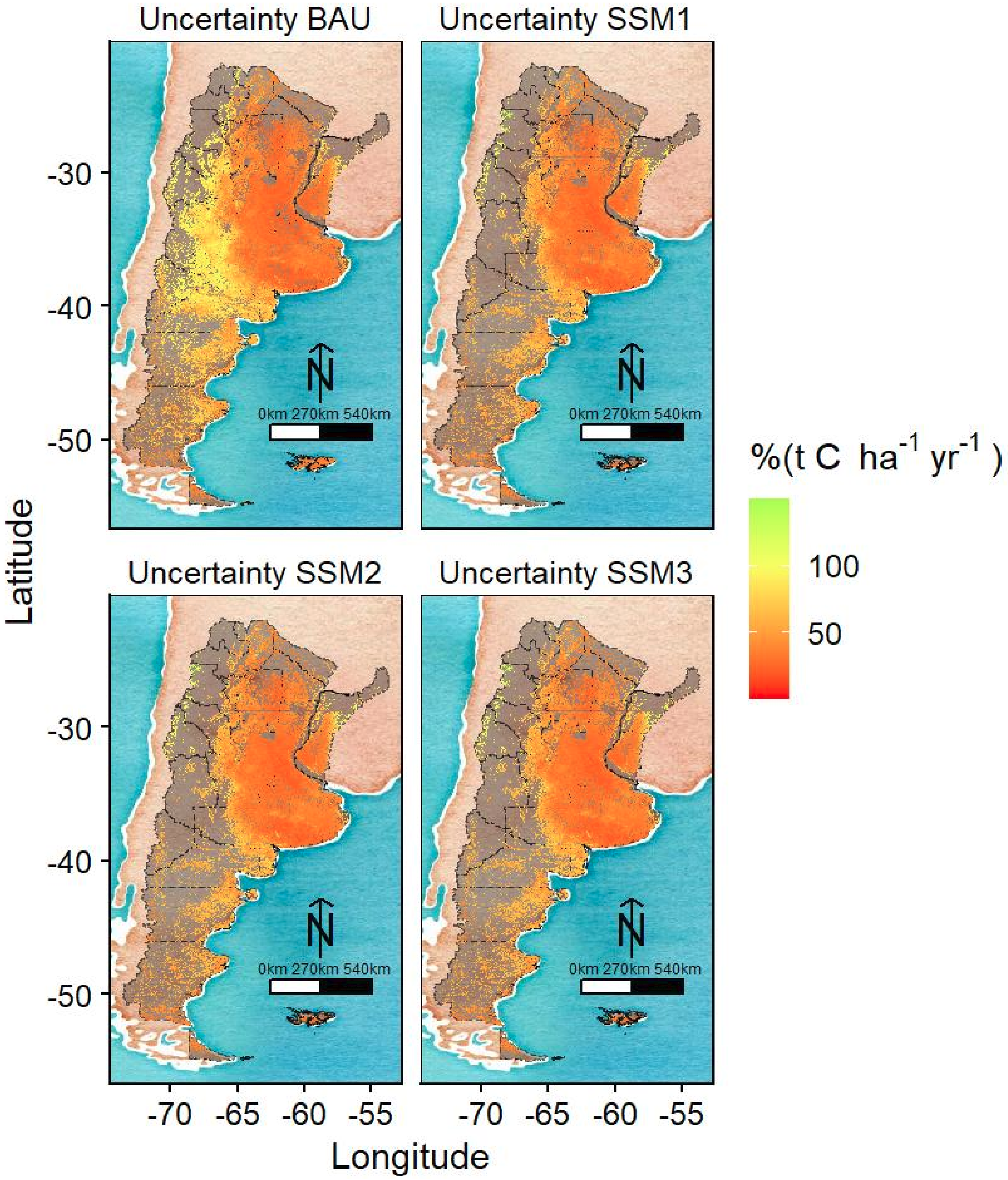

Figure 7. Uncertainty absolute SOC sequestration rates (ASR) expressed in percentage. Business as usual (BAU) model and the three hypothetical scenarios of SOC gains from the adoption of a sustainable soil management strategy.

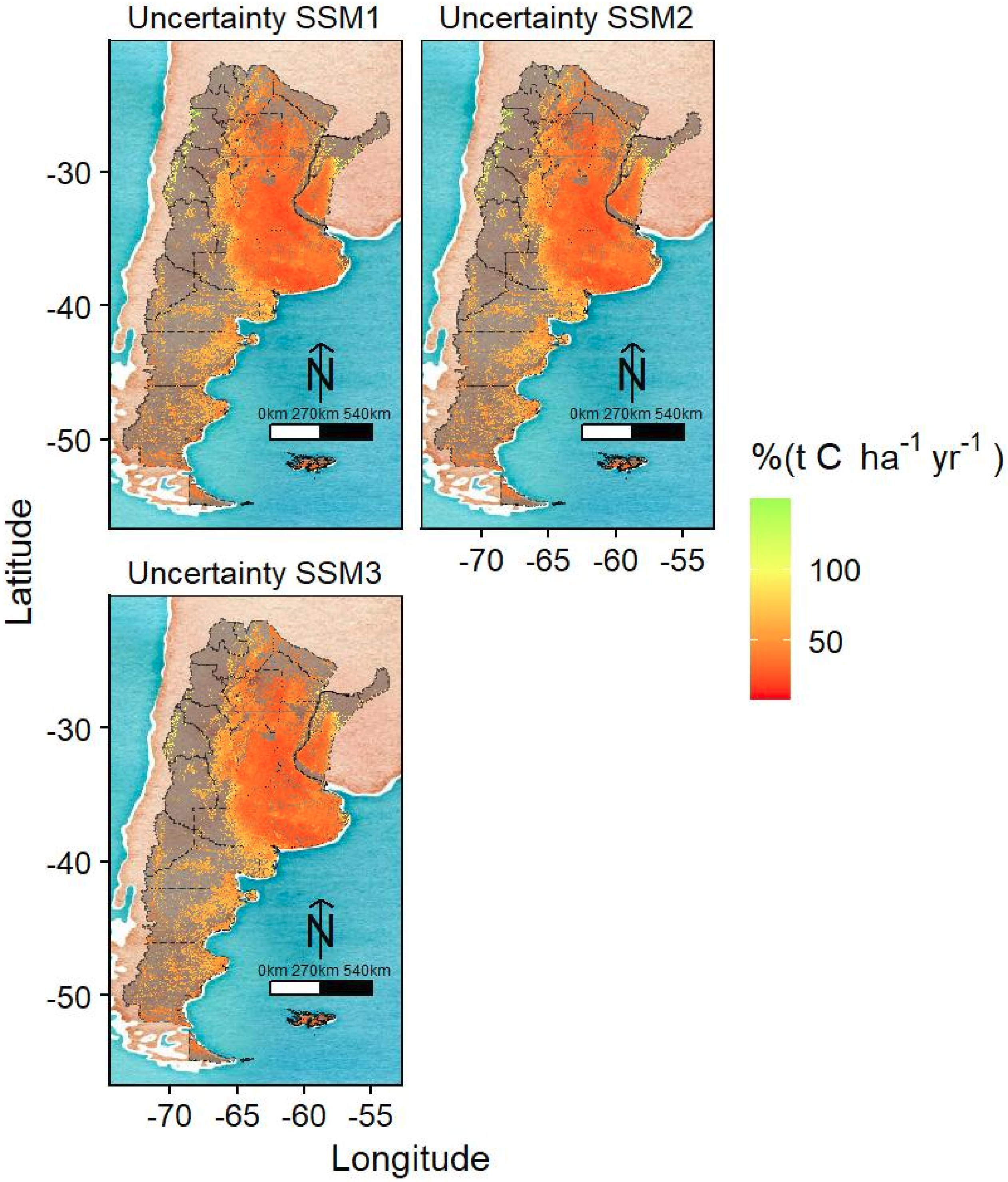

Figure 8. Uncertainty of relative sequestration rates (RSR) in the three hypothetical scenarios of SOC gains, from the adoption of a sustainable soil management strategy.

4. Discussion and relevant considerations

The use of the spatialized RothC model for Argentina was useful because we were able to estimate the SOC loss under the BAU practices, as well as, to estimate the increase in SOC stocks due to the implementation of SSM tending to increase C inputs. This study also allowed us to have a first approach to detect land uses, sites and regions with greater potential to increase SOC stocks after the use of SSM.

Our results suggest that at the national level, agricultural systems are currently a source of CO_2 rather than a net sink. Absolute sequestration rates for the BAU practices showed average negative values (-0.089 t C ha^{-1} yr^{-1}) and SOC losses in many regions (Fig. 2; Table 1). This trend in SOC losses with current agricultural systems are in line with the results of Sainz Rozas *et al.* (2011) and Sainz Rozas (2019), which have shown continuous reductions in organic matter contents for most regions in the last decades.

The projections also showed negative absolute sequestration rates for the SSM1 and SSM 2, indicating that even increasing C inputs by 5% to 10% would not be enough to achieve positive C balances by 2040 (Table 1; Fig 4 and 5). Our results suggest that, at the national level, a SOC sequestration scenario with a rate of at least 20% of increase in C inputs is needed for achieving SOC neutrality in Argentina, and a change from source to sink of atmospheric CO_2. These results show that current CO_2 emissions from SOC losses due to land management in current agricultural lands, other than those associated with land use change, may play an important role in Argentina GHG emissions. Efforts and research should be undertaken to include and better represent these emissions in the National GHG Inventory.

Our predicted absolute and relative SOC sequestration rates under the SSM scenarios are within the expected range of the effects of agricultural practices on SOC sequestration rates in other regions of the world (Lugato et al., 2014; Minasny et al., 2017). However, our results indicate lower magnitudes (in terms of tC ha^{-1} yr^{-1}) than the expected from previous field works in Argentina. For example, the inclusion of cover crops showed average SOC sequestration rates of 0.45 tC/ha/yr in the Pampa Region (Alvarez *et al*., 2017; Beltran et al., 2018; Romaniuk et al., 2018), fertilizer use showed an increment of around 0.18 tC/ha/yr (Duval et al., 2020; Restovich et al., 2019), and the inclusion of cycles with perennial pastures in crop rotations showed average SOC sequestration rates of 0.76 tC/ha/yr (Costantini *et al*., 2016; Gil *et al*., 2016). These results could be due to several reasons.

First, we are estimating average SOC sequestration rates in a 20 years period following FAO recommendations. After a change in management SOC changes tend to be higher during the first years, but then the change in SOC in time decreases as SOC stocks approach a new equilibrium level - plateau (Stewart *et al*., 2011). So average sequestration rates changes in a 20 years period are expected to be lower than those that could be found in the first 5 to 10 years after a management change, as in the case of field experiments.

Second, the results from published field experiments have been generally generated in the temperate Pampa Region. Our average SOC sequestration rates shown in Table 1 are integrating different soil and climate conditions, including a wide range of extra-pampean environments, with sub humid and arid climates and subtropical to cool temperature regimes, which could restrict net primary production and C inputs compared to the temperate and humid Pampa Region. The map from Fig 2 and 3 show, for the Pampa Region, sequestration rates that are in the range of the abovementioned published local data. Third, the maps were generated using standard scenarios, with 5%,10% and 20% increase in C inputs. These scenarios will allow us to compare results in an harmonized way with other countries, but could underrepresent the potential of current sustainable management practices in our conditions. For example, considering the inclusion of cover crops alone from published studies (Cazorla *et al*., 2017; Alvarez *et al*., 2017; Beltran *et al*., 2018; Romaniuk *et al*., 2018; Agosti *et al*, 2020), this practice could increase residue returns and hence carbon inputs to our soils by 30-50%. This increase is considerably higher than the used standard SSM scenarios. The future use of alternative scenarios adjusted by local data will enable us to simulate scenarios which better resemble the potential of the local practices.

Regarding the analyzed land uses, a greater SOC potential was observed in soils under agriculture (including mixed systems). This is possibly due to the fact that these soils in general may have a lower initial carbon concentration with respect to the grasslands and also because the croplands are located in optimal areas to sequester C due to their edaphoclimatic characteristics (% clay, temperature and humidity). Most areas considered under the “grazing” land use included unimproved grasslands and shrublands, located under semi-arid to arid climates, which could be limiting the simulated SOC sequestration potential of these land uses.

Despite the below expected SOC sequestration rates, the results showed that there is a large potential of Argentinean agriculture contributing to national-to-global mitigation of GHG emissions and climate change if SSM practices are encouraged. For example, under the projected SSM scenarios, which as discussed may be lower than the achievable increase in C inputs in local systems, a sequestration potential of 4.2 to 16.7 MtC.yr^{-1} can be expected, representing the mitigation of 15 Mt CO_2eq yr^{-1} to 65 Mt CO_2eq yr^{-1}. This indicates that conservatively, the wide adoption of sustainable soil practices could mitigate about 11-48% of current national agricultural emissions.

Besides its limitations, the results based on this approach can be used as an input for producers or certifiers willing to estimate regional SOC sequestration potential, used as an input within the country's SDG to determine Climate Change mitigation techniques; and to estimate sequestration and emissions from soils in CO_2 equivalent to collaborate with the national GHG inventory. This approach can be reproduced and improved in further versions as improved datasets (input layers, field results to validate results) become available and with the use of country specific inputs and model parameters, to increase the accuracy and and reduce uncertainties of SOC projections.

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