Development of technology extrapolation domains (TED's) for evidence-based site selection of SI-MFS intervention communities in northern Ghana

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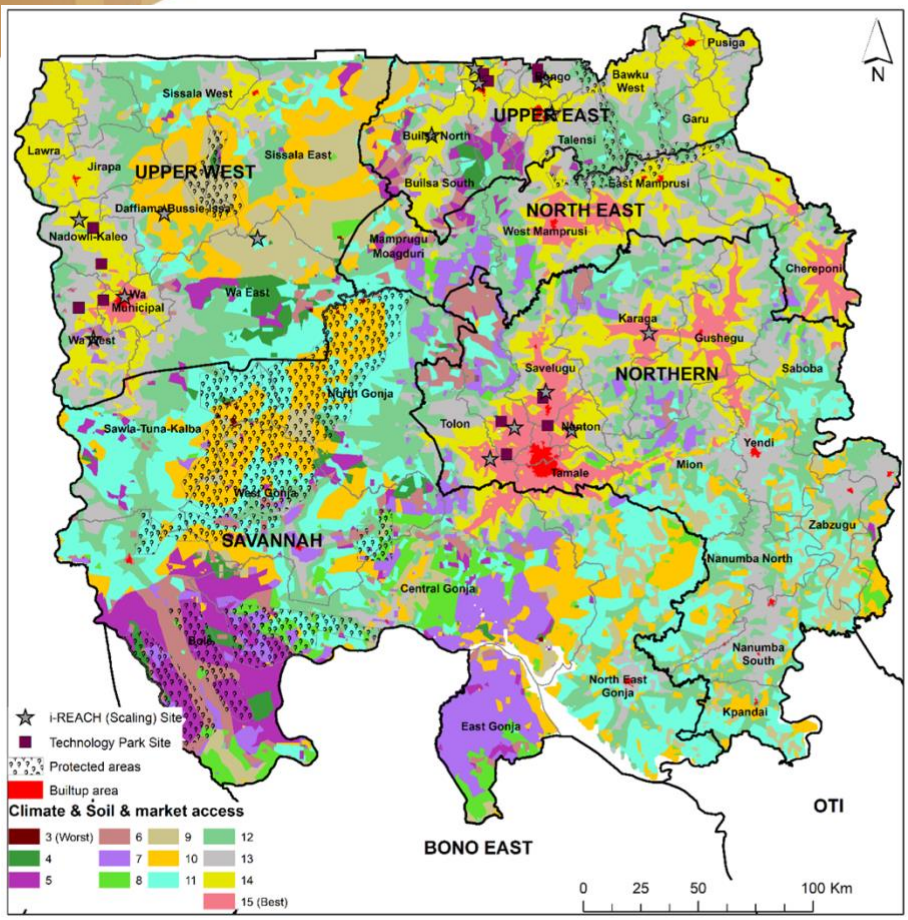

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The Sustainable Intensification of Mixed Farming Systems Initiative aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agroecologies and socio-economic settings.

Through action research and development partnerships, the Initiative will improve smallholder farmers' resilience to weather-induced shocks, provide a more stable income and significant benefits in welfare, and enhance social justice and inclusion for 13 million people by 2030.

Activities will be implemented in six focus countries globally representing diverse mixed farming systems as follows: Ghana (cereal–root crop mixed), Ethiopia (highland mixed), Malawi: (maize mixed), Bangladesh (rice mixed), Nepal (highland mixed), and Lao People's Democratic Republic (upland intensive mixed/ highland extensive mixed).

Contents

Acknowledgements

The study was funded by One CGIAR under the Sustainable Intensification of the Mixed Farming System Initiative (SIMFS). The Mixed Farming Systems Initiative aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agro-ecologies and socioeconomic settings. Implemented in Bangladesh, Ethiopia, Ghana, Laos PDR, Nepal, and Malawi; this Initiative works with a wide array of partners, including demand, innovation, and scaling partners from national agricultural research and extension systems, universities, local and international NGOs, farmer associations, agricultural administrations, international agricultural research centres, national governments, policymakers, and the private sector. Additional funding was obtained from Excellence in Agronomy (EIA) Initiative.

Background information

Sustainable Intensification of Mixed Farming Systems (SI-MFS) initiative is funded by One CGIAR under the Resilient Agrifood Systems action area. The SI-MFS initiative aims to provide equitable, gender-transformative pathways for improving the livelihoods of actors in seven prioritized mixed farming systems in six countries (Figure 1) through sustainable intensification within target agro-ecologies and socio-economic settings. In Ghana, the Initiative works in cereal-root crops mixed farming system with a wide array of the demand, innovation, and scaling partners from national agricultural research and extension systems, universities, local and international NGOs, farmer associations, agricultural administrations, international agricultural research centers, national governments, policymakers, and the private sector.

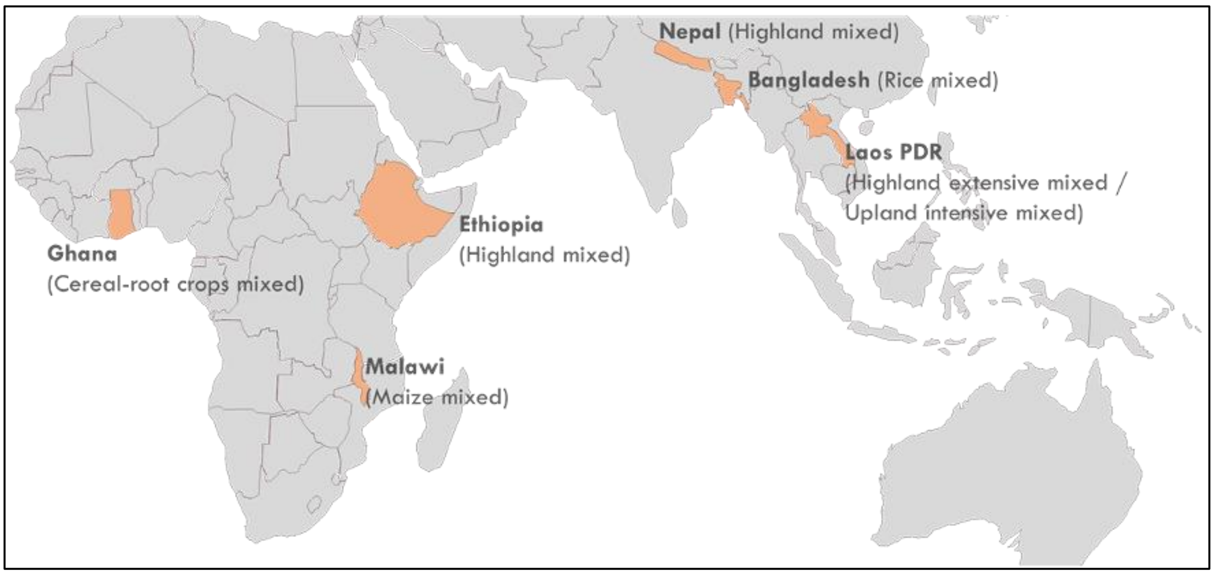

Figure 1. Focal farming systems and countries in the Sustainable Intensification of Mixed Farming Systems Initiative.

Targeting sustainable intensified socio-technical bundles of innovations to suitable biophysical and socio-economic context in the mixed farming systems reduces the chances of technology failure that in-turn promotes their adoption (Muthoni et al., 2017). The contiguous landscapes with relatively similar biophysical and socioeconomic characteristics are referred to as the technology extrapolation domains (TED's; Andrade et al., 2019). TED's are developed to identify the agro-ecological and socio-economic contexts where socio-technical bundles can be scaled out with the least risk of failure. Geospatial tools were applied to characterize the biophysical and socio-economic systems in northern Ghana to guide selection of sites for co-designing bundles of sustainable socio-technical bundles of innovations between researchers and farmers in northern Ghana. The bundles of technologies include improved cereal and legumes crop cultivars (maize, cowpea), good agronomic practices and integrated crop and livestock husbandry.

Material and methods

Multi-source spatial data representing biophysical and socio-economic conditions of the focus area were collated from different geodatabases (Table 1).

Table 1. Characteristics of geospatial data utilized to generate technology extrapolation domains

No	Variable name	Spatial Resolution	Span (years)	Units	Source
Precipitation					
1	TerraClimate Monthly precipitation	4 km	1958-present	mm	http://www.climatologylab.org/terraclimate.html
2	CHIRPS daily and monthly precipitation	5 km	1981-present	mm	https://www.chc.ucsb.edu/data/chirps
Temperature					
3	CHIRTSMax monthly maximum temperature	5 km	1983-2016	°C	http://www.climatologylab.org/terraclimate.html
4	CHIRTS-daily maximum and minimum temperature				
5	Terraclimate minimum temperature		1958-2019		
Actual evapotranspiration					
6	Terraclimate monthly actual	4 km	1958--present	mm	http://www.climatologylab.org/terraclimate.html

	evapotranspiration				
Soil variables: SoilGrids					
7	Extractable magnesium	250m	2017	mg/kg (ppm)	https://www.isda-africa.com/isdasoil/
8	Total nitrogen			mg/kg (ppm)	
9	pH			pH – values (soil pH/10)	https://www.isda-africa.com/isdasoil/
10	Bulk density			kg/m^3	
11	Cation Exchange Capacity			cmolc/kg (fine earth)	
12	Clay content			g/100 g (w%)	
13	Sand content				
14	Silt content				
15	Soil Organic Carbon			g/kg	
Socioeconomic variables					
16	Cattle density-weighted	~10 km	2010	Heads	http://www.fao.org/livestock-systems/global-distributions/en/
17	Market access	~1 km	2019	minutes	https://www.map.ox.ac.uk/accessibility_to_cities/
18	Human population	~1 km	2015	Count/density	https://www.worldpop.org/
Terrain variables					
19	ASTER digital elevation model (DEM)	~30 m	2018	m	https://asterweb.jpl.nasa.gov/gdem.asp
Ancillary variables					
20	Administrative boundaries		2020		https://gadm.org/

Generating the technology extrapolation domains (TEDs)

Agroclimatic zones (ACZs) were delineated from a digital elevation model (DEM) and the annual time series of the Climate Hazards Group InfraRed Precipitation with Station version two (CHIRPS-v2) precipitation data and the Terraclimate minimum and maximum temperature spanning 40 years period (1981 – 2021). The K-means clustering algorithm was utilized to classify four relatively homogenous agro-climatic zones (Figure 2). The four ACZ's are biophysical basis for making agricultural extension policies rather than political boundaries that are artificial. The cluster analysis enabled identification of administrative units that occur in similar ACZ, and therefore have similar agro-ecological potential. Table 2 shows the average values of the elevation and climatic layers in the four ACZ's in northern Ghana.

Figure 2. Four relatively homogenous agroclimatic zones delineated by Kmeans clustering of the gridded elevation, rainfall, and temperature layers in the northern Ghana.

Table 2. Average values of the elevation and climatic layers in the four agroclimatic zones in northern Ghana

Climate zones	Annual Rainfall (mm)	Annual minimum temperature (°C)	Annual maximum temperature (°C)	Elevation (m asl)
1	1,052	22.54	32.67	191.58
2	1,049	22.12	33.72	185.66
3	968	21.73	34.08	247.03
4	1,190	22.30	33.18	140.86

Soil physio-chemical properties zones

Gridded layers representing soil physical and chemical property maps of Africa by iSDA (0-20cm depth) at a spatial resolution of 30m were aggregated to 30 arc-seconds (about 1 km²). Similarly, K-means clustering algorithm was applied to define four relatively similar soil zones in northern Ghana (Figure 3).

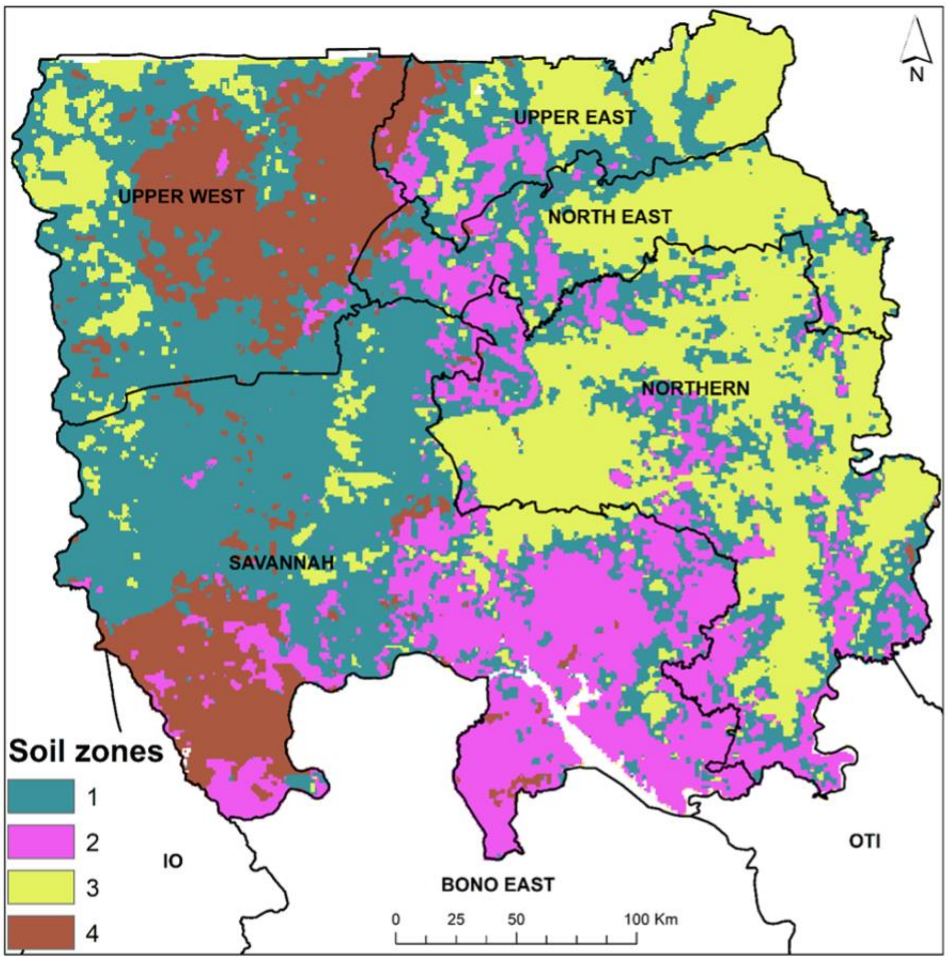

Figure 3. Four relatively similar soil zones derived from gridded soil physical and chemical properties in northern Ghana.

Table 3. Mean soil physio-chemical properties in in northern Ghana

Soil Zone	Bulk density (kg m-3)	Cation Exchange Capacity (cmol(+) kg-1)	Extractable potassium (mg kg-1)	Nitrogen (g kg-1)	Organic Carbon (g kg-1)	Phosphorus (mg kg-1)	pH (water)	CLAY (%)	sand (%)	silt (%)
1	1,280	10.94	67.82	77.9	19.58	7.39	5.97	18.48	54.67	23.23
2	1,401	10.37	62.89	63.8	18.87	6.96	5.92	14.68	61.55	21.99
3	1,465	10.14	67.00	65.8	18.89	7.02	5.96	12.92	67.19	17.02
4	1,291	10.82	59.74	75.6	18.94	7.60	5.88	16.20	59.87	22.87

Intersection of agroclimatic and soil zones

The agroclimatic and soil physio-chemical properties zones layers were intersected to produce sixteen soil-climatic zones (Figure 4). The total area (size), human population and average time to the nearest market with over 20000 inhabitants were calculated for each of the 16 soil-climatic zones (Table 4).

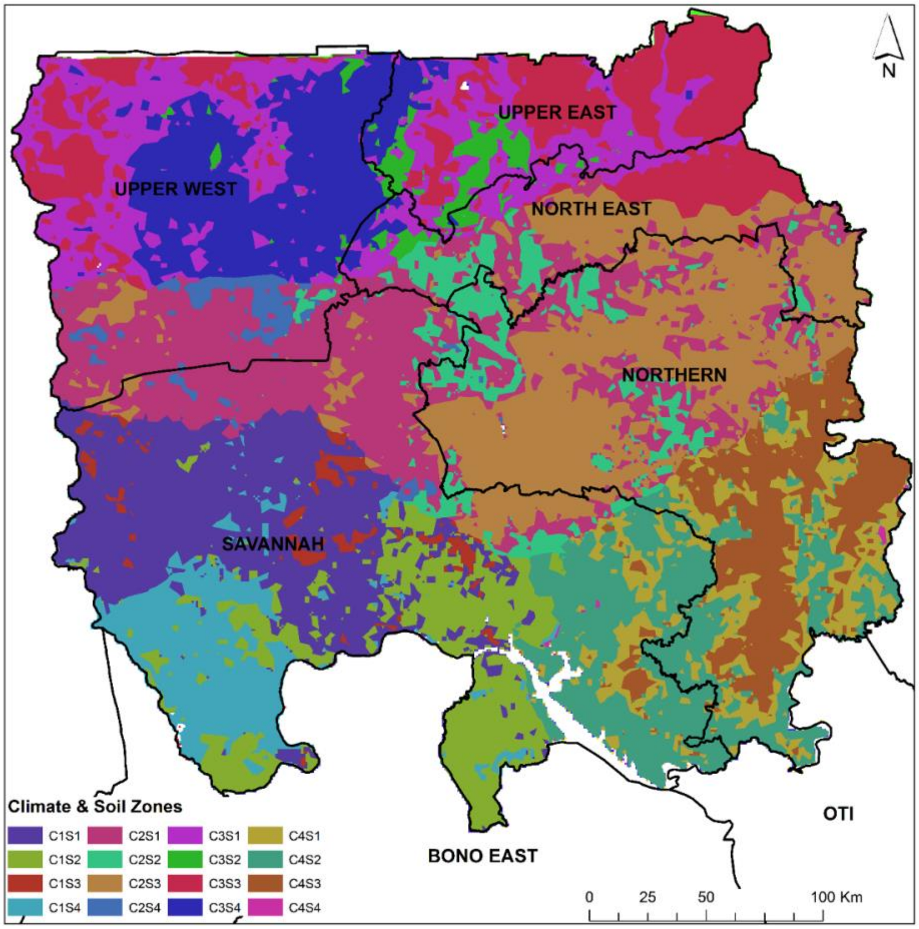

Figure 4. Sixteen soil-climatic zones generated from intersection of agro-climatic and soil zones in northern Ghana

A layer representing distance to markets' was obtained from Weiss et al. (2018). This represented the distance in minutes taken to travel to the nearest town with over 20000 inhabitants (Figure 5).

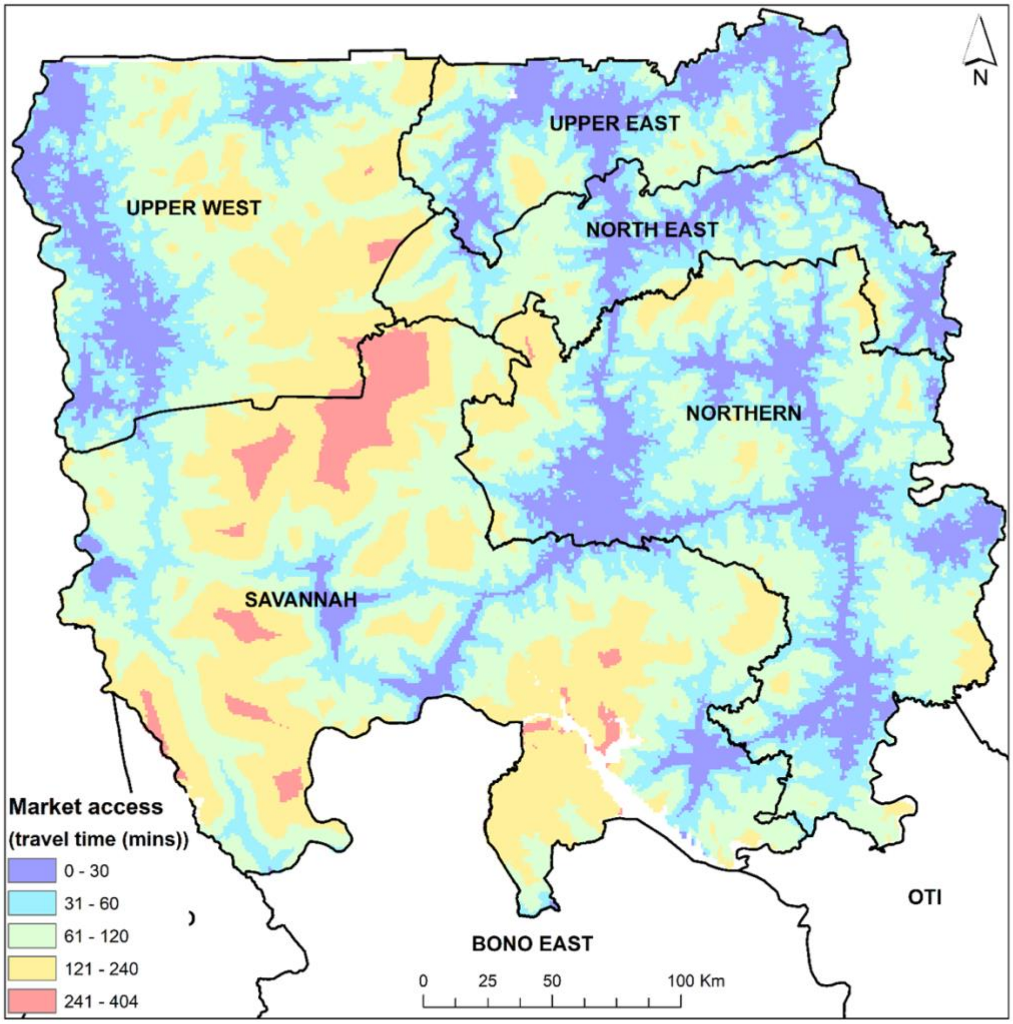

Figure 5. Market access represented as time in minutes taken to travel to the nearest market centre with over 20000 inhabitants in Northern Ghana.

The three variables (area, population and market access) were reclassified into five categories based on the quantile classification scheme (Table 4) with 5 being the best for targeting technologies when considering the area and population but 1 was the best in case of the market access since it represents the shortest distance to markets (Table 4).

Table 4. Classification of area, the population and market access in the soil-climatic zones

Area (Km^2)	Total human population (persons)	Area and population class codes	Market access (minutes)	Market access class code
< 1,500	<50,000	1	0 - 30	5
1,500 – 5,000	50,000 - 100,000	2	31 - 60	4
5,000 – 7,500	100,000 - 250,000	3	61 - 120	3
7,500 – 10,000	250,000 – 500,000	4	121 -240	2
> 10,000	>500,000	5	>240	1

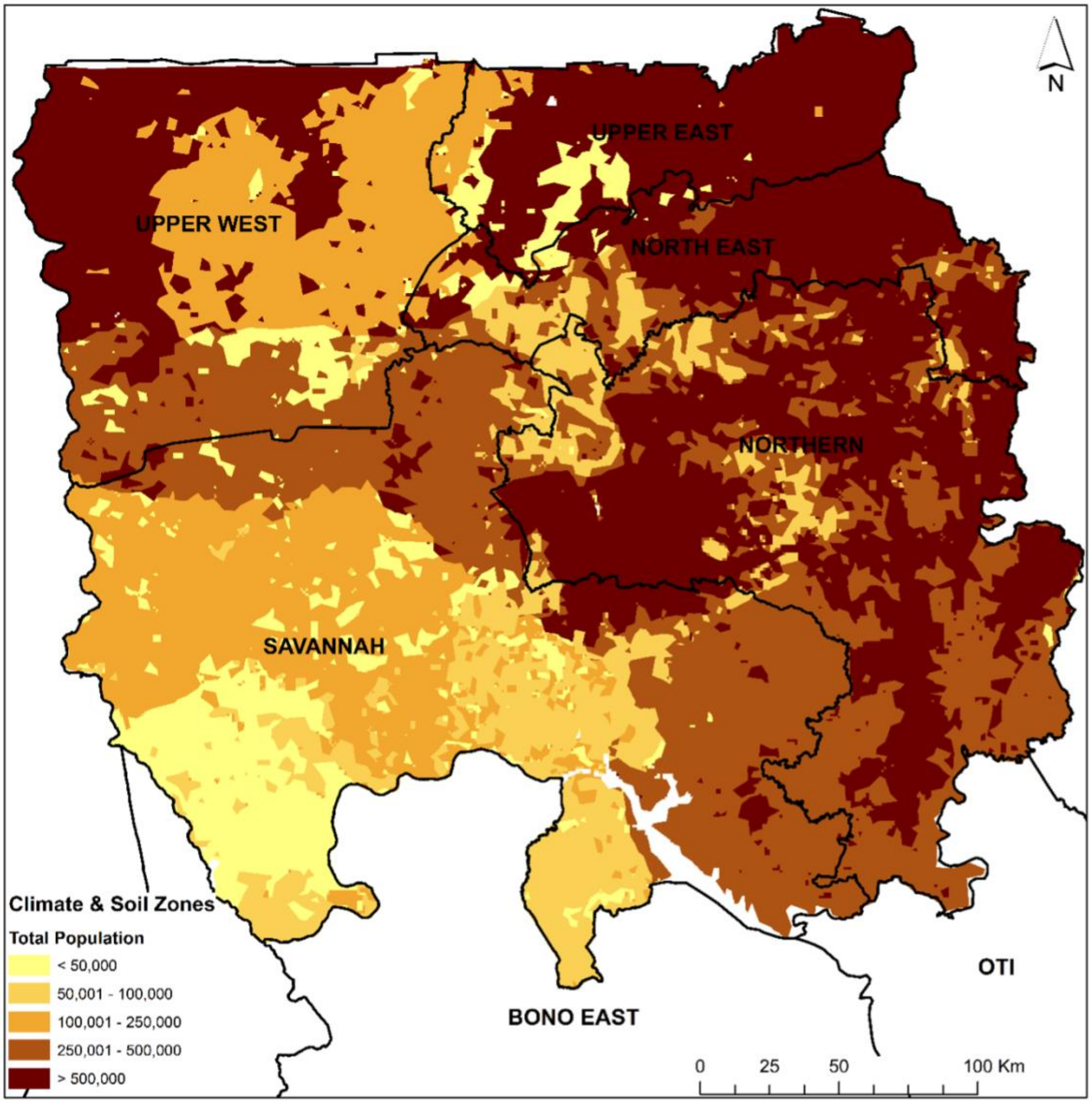

Figure 6. The total population living the sixteen soil-climatic zones identified in northern Ghana.

Two types of sites were considered for SI-MFS initiative in Ghana and these sites were technology parks and Innovation Research Extension Advisory Coordination Hub (i-REACH). The technology parks sites are for codesigning and validation of sustainable intensified socio-technical bundles whilst the i-REACH sites are for scaling out of validated sustainable intensified socio-technical bundles. For the technology park site selection, previous investments (in terms of established technology parks and sustainably intensified technologies generated from past CGIAR research and Africa RISING project) and the ability of a community to provide 1-2 acres of arable land within the community for the establishment of technology park (Figure 7) were used in addition to the TEDs domains (Figure 8). Leveraging on the previous investments helps the Initiative to build on and fill identified knowledge gaps related to interactions of system components for higher impact within a short period of time. Similarly for the i-REACH sites we considered the presence of district or municipal department of agriculture of local government of Ghana (DDA/ MDA) and the ability of the DDA or MDA to provide 1 acre of arable land around the office compound within the TED domains (Figure 8).

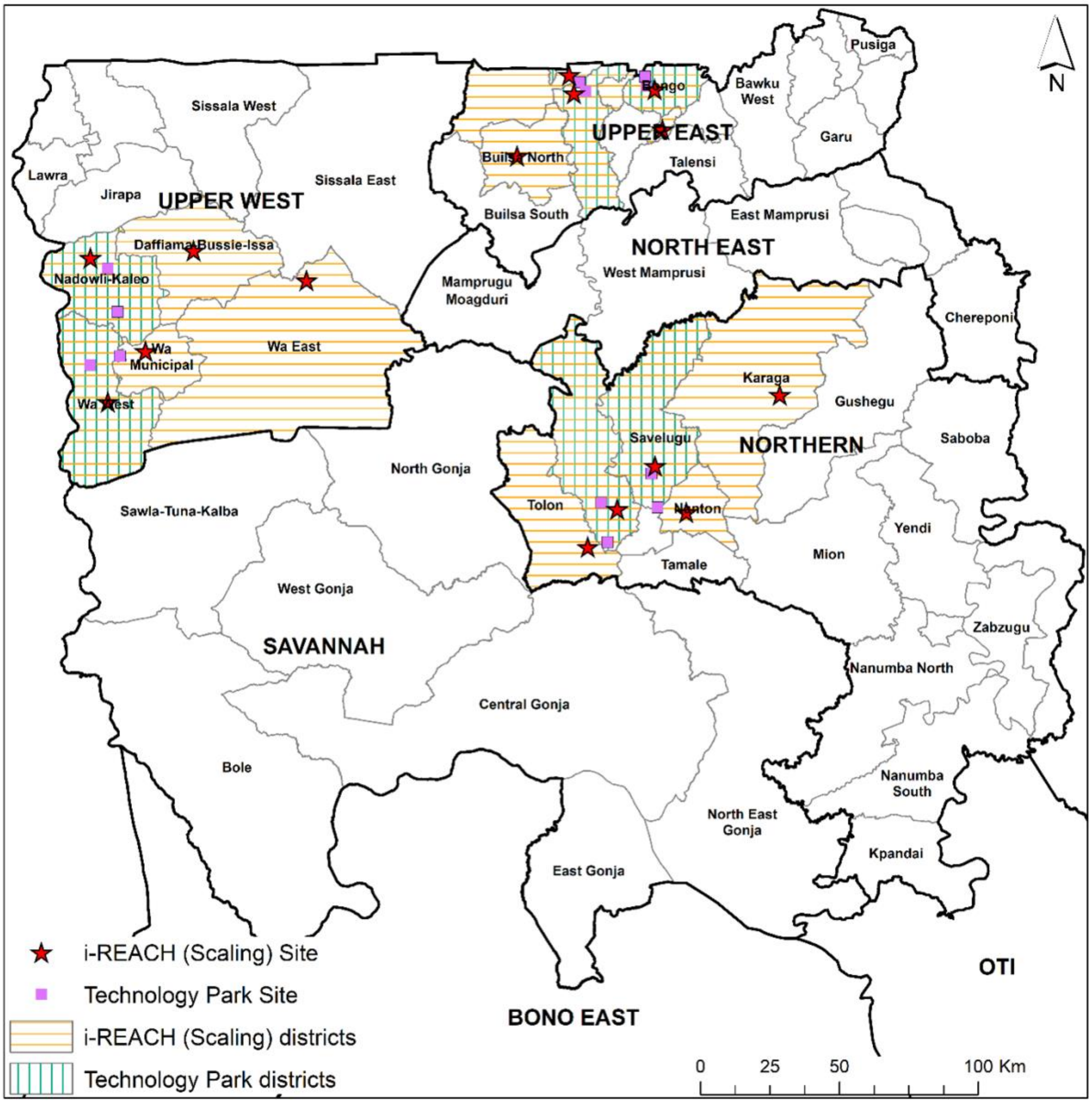

Figure 7. Intervention districts/ municipals from previous investments on validated sustainably intensified socio-technical bundles of innovations and technology parks.

The weighted score of the three criteria were accumulated in each pixel, resulting to 13 priority zones in northern Ghana (Figure 8). The higher the value, the higher the suitability for co-designing and scaling out of sustainable intensified socio-technical bundles. Therefore, the zones with value 15 should be prioritized for co-designing and scaling out of socio-technical bundles because they have the best biophysical and socio-economic potential. The protected areas are masked out to ensure conservation of biodiversity that provides critical ecosystem services.

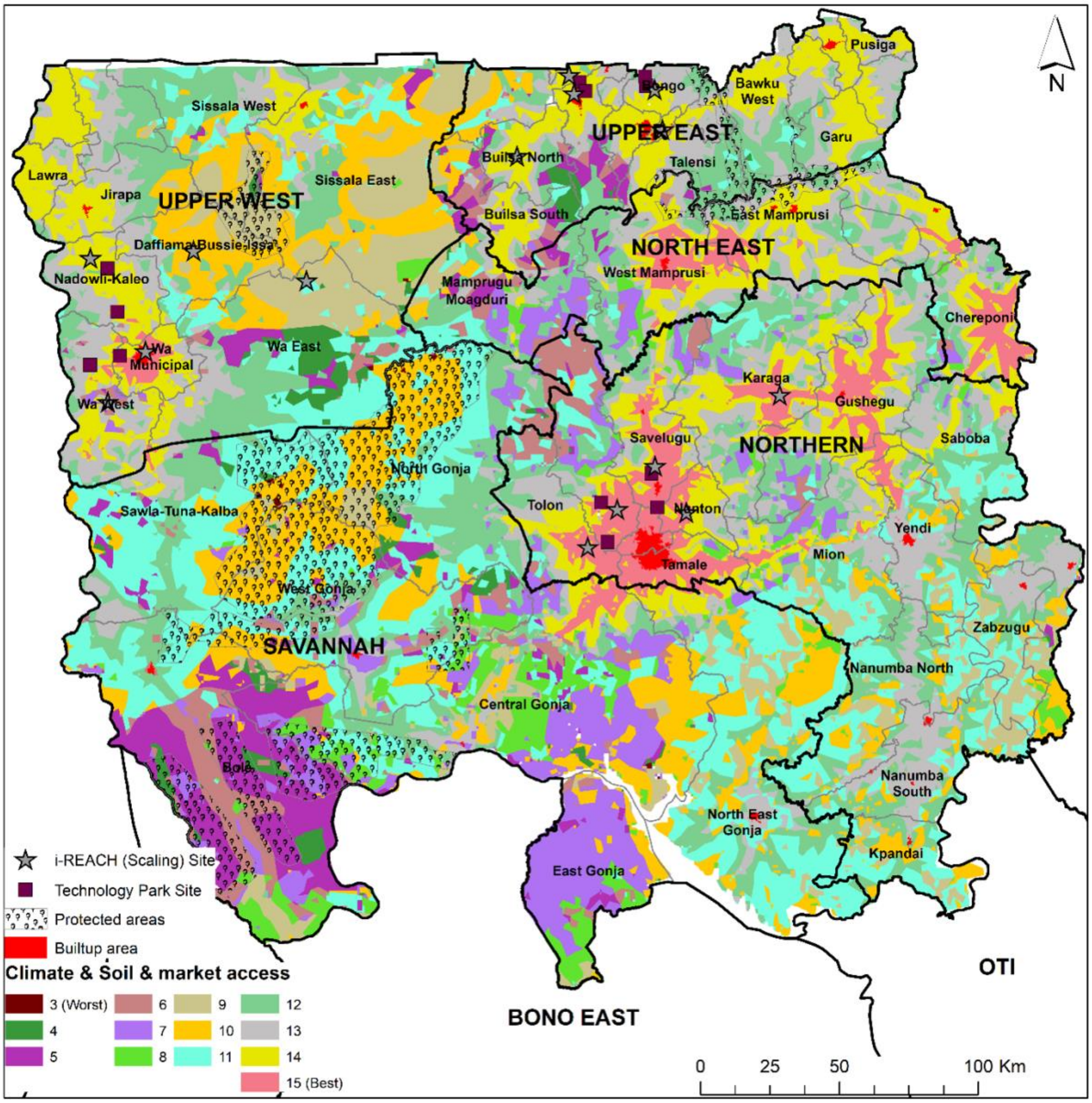

Figure 8. The technology extrapolation domains generated from cumulative score ranking based on the area occupied by zones, total population, and market access. The ranking criteria is presented in Table 4. The higher the rank value, the most suitable the zone is for targeting the sustainable intensified socio-technical bundles.

Conclusions

This report presents a simple evidence-based method for objectively selecting and prioritizing the intervention sites for co-design or scaling of sustainable socio-technical bundles of innovations in cereal-root crops mixed farming systems of northern Ghana. This method is particularly applicable in other areas with limited agronomic trials that would rather be used as reference for a bottom-up extrapolation. A map was produced ranking the suitability of the entire zone for scaling out sustainable intensification technologies. This map will guide extension agencies on prioritizing the intervention sites to ensure successful wider adoption while maximizing the impact of limited resources. One limitation of the approach is that it assumes the biophysical and socio-economic layers have equal weights. This may need improvement through a stakeholder's consultations so that they rank the contribution of variables followed by a hierarchical multicriteria decision making approach.

References

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