Hydrological Study: Assessment of the Current Status, Climate Change and EbA Impacts at district level

for the

Resilient Puna

Ecosystem based Adaptation for sustainable high Andean communities and ecosystems in Peru

As of November 2023, v.02

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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1 Foreword

This study aims to perform an hydrological analysis of the ecoregion in Peru above 3,500 m asl, called Puna. The domain of interest of this hydrological study consists primarily of grasslands, wetlands (locally known as bofedales), peatlands (turberas in Spanish), and some reed beds. Some relicts of high Andean forests also persist.
The hydrological analysis of the Puna ecosystems (peatlands, wetlands, and grasslands) and services they provide (provision and regulation of water; provision of fodder, food, and fiber; nutrient and carbon regulation) in the Southern High Andes of Peru (SHAP) aims to specifically cover five regions: Lima, Puno, Cusco, Arequipa and Apurimac.

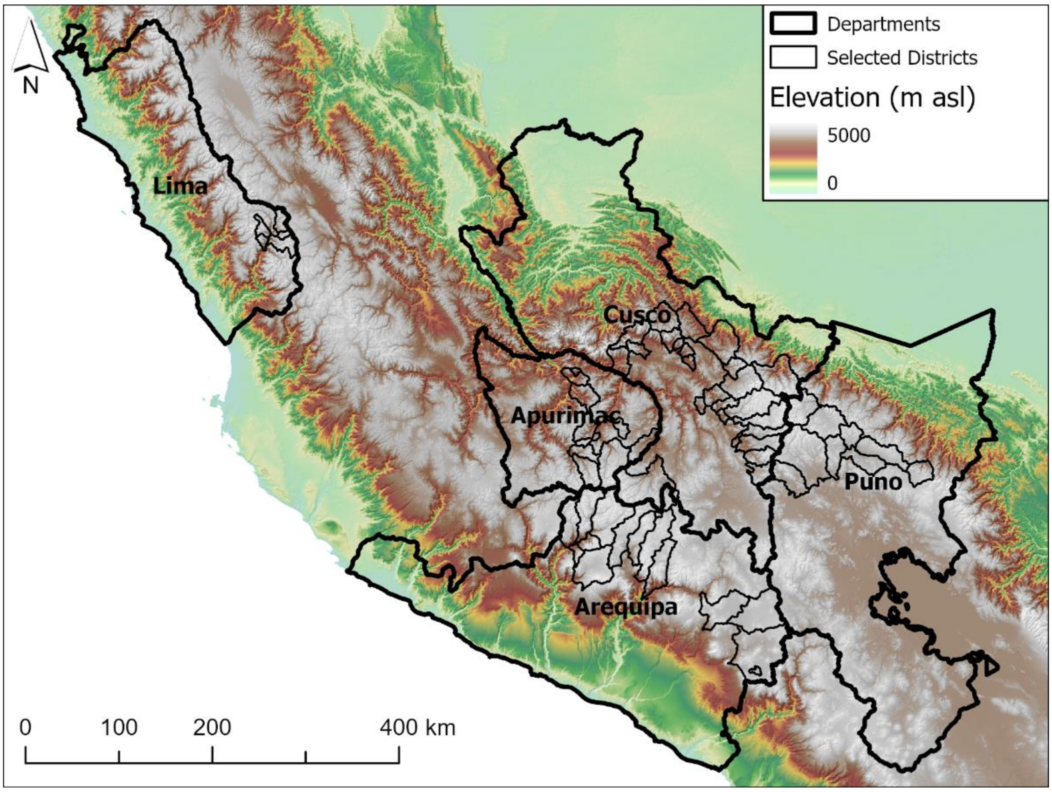

Figure 1. Map of the selected Departments and Districts of Peru in this study

This study was conducted in order to address the following points:

- Describe the status of the hydrological system;
- Describe how it will be affected by climate change;
- What would be the status of the system with the EBA measures promoted by the project?

The tackling of these three questions would determine a large set of know biophysical-hydrological variables at proper scale and resolution (e.g. geospatial data, time series, etc.). Considering the limited availability of such data related to current/projected water resources management systems, water usages as well as the characteristics of the hydraulic infrastructures, a parsimonious hydrological analysis was conceptualized, tested and implemented. The proposed simplified hydrologic analysis considers hydrological and climate variables that are available as gathered from open data and scientific literature in order to assess actual and future hydrological states and dynamics as a function of changing climate and the effect of the EBA measures in the study districts. The selected hydrological analysis supports calculation of hydrological and climate resource and risk indexes addressing the three main point above and in particular supports the understanding and estimation of water availability versus water usages and EbA measure impacts, given the suitability of each district for each EBA implementation.

Given the limited available hydrological data on the study area at local scale, the analysis cannot quantitatively estimate hydrological benefits of the EbA on it. In fact, specific information on the single EbA measures (structural dimensions, extensions, drawings of the design interventions, etc.) needs to be provided. However, the analysis identifies the districts that are potentially critical in terms of water use as respect to the water availability and thus would receive more benefits from the EbA considering the actual and future climate scenarios.

Note that the presentation of this study was validated with the project partners and with professionals from peruvian ministries (Ministry of Agrarian Development and Irrigation, Ministry of Environment), institutions (Regional Hydrological Initiative of Andean Ecosystems, CARE Peru) and universities (Imperial College London). The methodology was understood by the participants in terms of its inputs, development, scope and results, and validated by them. Recommendations were considered for this next version.

2 Methodology

The adopted methodology carried out to classify the Puna districts as respect to the relative impact of EbA measures considered the spatial distribution current and climate change variables related to water usage and water resources availability (Sections 2.2, 2,3 24.1) as well as the spatial distribution of the suitability of each EbA following the Annex 2e. “Geospatial Analysis Determining suitability of area for the implementation of Ecosystem based Adaptation measures in selected value chains” (Section 2.4.2).
The following subsection will dig into each of the abovementioned factors.

2.1 Hydrological data framework

For each District, we considered different hydrological variables related to the current status of the water resources availability and usages as well as to process climate change scenarios (*Table 1*).

Table 1. List of the variables identified for the hydrological analysis

Type	**Variable**	**Acronym**	**Unit**	**Aggregation**	**Source**
Current Status	Annual average discharge at sub-basin pour point	DIS	m3/s	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Annual average land surface runoff in subbasin	RUN	mm	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Annual average potential evapotransipration upstream of sub-basin pour point	PET	mm	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Annual average precipitaton	PRE	mm	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Sum of reservoir volume upstream of sub-basin pour point	VOL	Mm3	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Snow Cover Extent upstream of sub-basin pour point	SCE	%	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019

Current Status	Glacier Extent upstream of sub-basin pour point	GLA	%	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Cropland Extent upstream of sub-basin pour point	CRP	%	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Pasture Extent upstream of sub-basin pour point	PAS	%	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Irrigated Area Extent (Equipped) upstream of sub-basin pour point	IAE	%	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Population Count upstream of sub-basin pour point	POP	#	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Current Status	Urban Extent upstream of sub-basin pour point	URB	%	Sub-basins (Hydroatlas at the maximum detail: level 12)	Linke et al., 2019
Climate change	Glaciers elevation changes between 2000 and 2016	GEC	mm	Points where measurements were collected	Copernicus Climate Change Service
Climate change	Changes in Precipitation trends by district	PTR	%	Districts	SENAMHI

These variables were used to combine different indexes that can be related to the ratio between the water usage and water availability. These indexes were ranked ad weighted in order to define the relative hydrological status of each district as respect to the other ones. The Hydroatlas (https://www.hydrosheds.org/hydroatlas) subbasins – from which hydrological variables of the current status were collected at the maximum detail (level 12) – have a much lower extension as respect to the district dimensions (*Figure 2*). Therefore cumulated averages (e.g. precipitation) or sum variables (e.g. population count) were used among the sub basins belonging to a specific district.
Note that “Glacier Extent” and “Sum of reservoir volume” were not available for most of the study area, therefore these variables were not considered for the analysis.

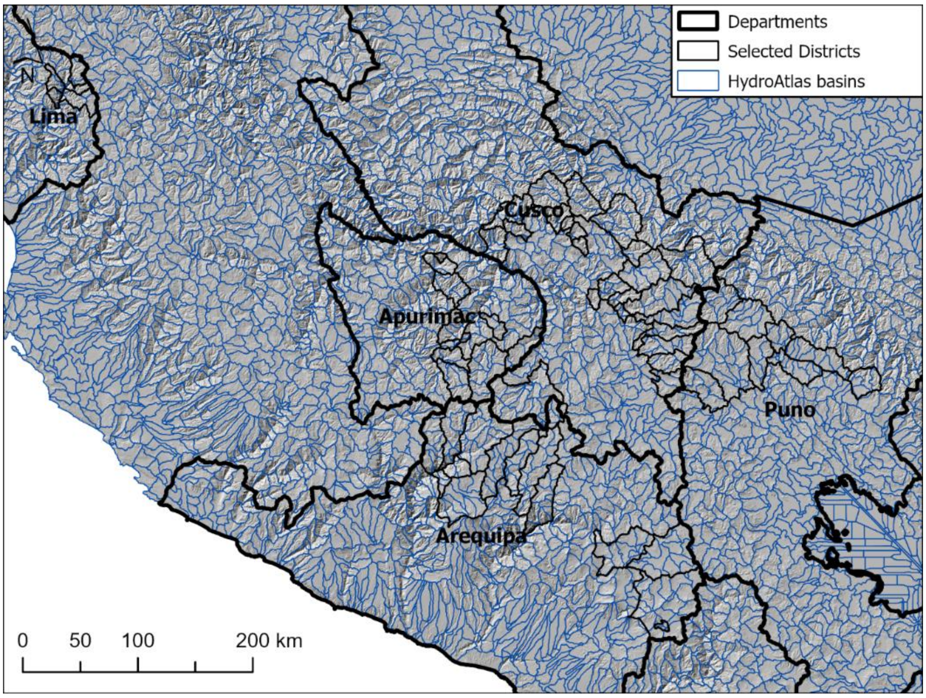

Figure 2. Map of the HydroAtlas basins

Data on change in precipitation trends were collected from the report "*De la Cruz, G. (2021). Escenarios climáticos: Cambios en los extremos climáticos en el Perú al 2050*" and reported in the hydrlogical study (EH Resilient Puno 20230516.docx). These data refer to the high emissions 'RCP8.5' global warming scenario projected to the 2050.

2.2 Analysis of the current hydrological status

2.2.1 Current status Indexes

We defined 25 indexes relating water usages and water availability as reported in Table 2. These indexes do not provide detailed information on the current status of the water resources management of each district, but charactise an effective assessment of the study domains in relation to the questions to be addressed in hydrologic terms. The selected indexed hydrological variables can be considered as a proxy for defining the status of the hydrological system among the districts in relative terms (e.g. considering comparative district versus district, or actual versus future etc). Note that the indexes related to the Discharge variable of each sub-basins were divided for the upstream area of sub-basin pour point (Area).

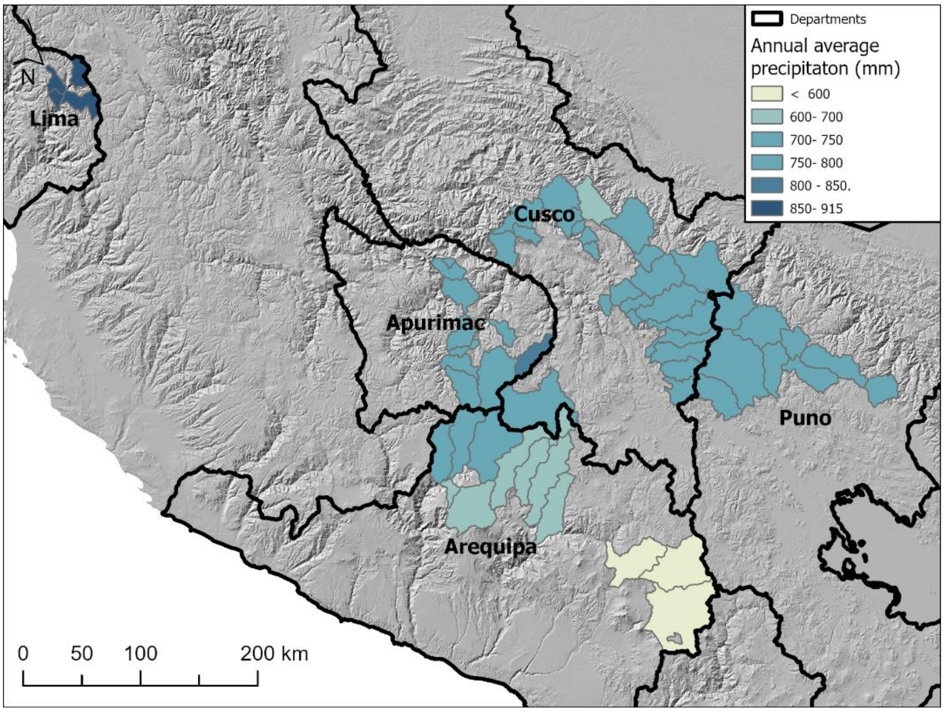

Figure 3. Example of a spatially distributed representation of the hydrological variables (Annual average precipitation) aggregated by districts

Table 2. List of the indexes calculated as indicators of water usages as respect to the water availability

	Water usage variables				
Water resources variables	CRP	PAS	IAE	POP	URB
DIS	CRP/DIS/ Area	PAS/DIS/ Area	IAE/DIS/ Area	POP/DIS/ Area	URB/DIS/ Area
RUN	CRP/RUN	PAS/RUN	IAE/RUN	POP/RUN	URB/RUN

PET	CRP/PET	PAS/PET	IAE/PET	POP/PET	URB/PET
PRE	CRP/PRE	PAS/PRE	IAE/PRE	POP/PRE	URB/PRE
SCE	CRP/SCE	PAS/SCE	IAE/SCE	POP/SCE/ Area	URB/SCE

The higher is the index, the higher is the water usage as respect to the water availability, with the exception of the ones related to the potential evapotranspiration (PET), for which the higher is the value, the lower is the available surface/ground water availability.

2.2.2 Weights

We defined different weights related to each variable in order to consider their different impact on water management (Table 3). For example, we gave more importance to cropland extent as respect to the urban extent. Note that the weight of the index will be given by the product of the weights of the variables involved in the index calculation. The weighted i-index given by the x and y variables for the d-district is given by the following expression:

$$WI_{id} = I_{xy} \cdot w_x \cdot w_y$$

where w_x and w_y are the weights of the variables x and y of Table 1. Weights assigned to each variable are reported in the Annex 1.

2.2.3 Index normalization and aggregation

Each index has been normalized considering the maximum values obtained for each district (NWI_{id}=$WI_{id}/max_i(WI_{id})$). Therefore, the whole normalized water index (NWI) for the *d*-district is given by the sum of the normalized indexes obtained for the *d*-district:

$$NWI_d = \sum_i NWI_{id}$$

The NWI for each district is an indicator of how the single district is affected by the water usage considering the water availability, as respect to the other districts.

2.3 Analysis of climate change impacts

2.3.1 Climate change indexes

A similar analysis on the climate change effect was performed considering climate change related variables. We defined 10 climate change indexes considering the same water resources variables used for the current status and two climate change variables (Glacier elevation change and precipitation changes).

Table 3. List of the indexes calculated as climate change indicators.

	Climate change variables	
Water resources variables	*GEC*	*PTR*
DIS	GEC/DIS/ Area	PTR/DIS/ Area
RUN	GEC/RUN	PTR/RUN
PET	GEC/PET	PTR/PET
PRE	GEC/PRE	PTR/PRE
SCE	GEC/SCE	PTR/SCE

For the climate change variables, negative values are related to negative effects of climate change on the current status, and vice versa.

2.3.2 Index normalization, aggregation and classification

We applied the same methodology illustrated in “Analysis of the current status” Section to normalize and aggregate the climate change indexes (CCI_d). Moreover, the indexes were classified in four different classes with almost the same sample size considering the index values. The Reclassified Climate Change Index for the d-district ($RCCI_d$) was done in order to assign values from 0.25 to 1 with the descending values of the CCI_d indexes. Therefore, higher values of the reclassified values were related to higher impact of climate change on each district.

2.4 Relative EBA impact of each district

2.4.1 Impact of water stress

To evaluate the impact of the EBA on each district, a combined Index (CI) considering climate change and current state variables was defined as the product of the two normalized current and climate change indexes defined in the previous sections:

$$CI_d = NWI_d \cdot RCCI_d$$

These values were reclassified in four classes representing respectively minor, moderate, major, high categories of relative water stress considering the current status and climate change effects.

2.4.2 EbA suitability ranges

For each District, the extent where each of the EbA measure was low, medium, high suitable was available (See "Geospatial Analysis Determining suitability of area for the implementation of Ecosystem based Adaptation measures in selected value chains" Annex 2e (1) document). Therefore, for each *d*-district and *e*-EbA, a total value of EbA suitability index ($ESI_{d,e}$) was calculated multiplying the absolute value of the areas belonging to a specific suitability category ($A_{d,e,k}$) for a specific weight (W_k) as a function of the suitability class:

$$ESI_{d,e} = \sum_{k=1}^{3} A_{d,e,k} W_k$$

The assigned weights for each suitability class are reported in the following table.

Table 4. List of the weights assigned to each EbA suitability class

EbA Suitability	Weight
Low	0.2
Medium	0.5
High	1

2.4.3 EbA impact matrix

The relative impact of the each EbA measure was evaluated considering both the impact of water stress and the EbA suitability range. In fact, the higher is the relative water stress the higher is the need of EbA measures that can have an higher impact with higher values of their suitability in a specific district. Therefore each district can be allocated in a EbA impact matrix as the following:

	EbA Suitability		
Water stress	*Low*	*Moderate*	*High*
High			
Major			
Moderate			
Minor			

Figure 4. Example of an EbA Impact matrix

Each district can be allocated in one of the coloured cell of the matrix considering its ranges of water stress and EbA suitability.

Moreover, a value of EbA impact was calculated as product of the EbA Suitability index (ESI) by the combined Current and Climate change Index (CI). Values were normalized in order to obtain ranges from 0 to 1.

3 Results

3.1 Analysis of the current status

The following tables report the values of the Normalized Water Index (NWI) illustrated in the methodology. Values vary from 0 to 1. The higher is the value, the higher is the water demand as respect to the water availability.
The spatial distribution of the NWI is reported in the Annex 2 (*Figure 6*).

Table 5. Results of the Normalized Water Index (NWI) for each District – Department: APURIMAC

District	NWI
ABANCAY	0.229
ANTABAMBA	0.571
CHUQUIBAMBILLA	0.439
HAQUIRA	0.212
HUAQUIRCA	0.525
LAMBRAMA	0.211
OROPESA	0.591
PATAYPAMPA	0.498
PROGRESO	0.481
TAMBURCO	0.217

Table 6. Results of the Normalized Water (NWI) Index for each District – Department: AREQUIPA

District	NWI
CAYARANI	0.44
CHACHAS	0.413
CHOCO	0.359
COTAHUASI	0.521
HUAYNACOTAS	0.619
ORCOPAMPA	0.413
PAMPAMARCA	0.633
PUYCA	0.673
SALAMANCA	0.774
SAN ANTONIO DE CHUCA	0.42
SAN JUAN DE TARUCANI	0.338
YANQUE	0.39

Table 7. Results of the Normalized Water Index (NWI) for each District – Department: CUSCO

District	NWI
ACOMAYO	0.204
CALCA	0.269
CCARHUAYO	0.648
CHALLABAMBA	0.25
CHECACUPE	0.244

CUSIPATA	0.227
HUAROCONDO	0.239
LAMAY	0.369
LARES	0.312
LAYO	0.419
LIMATAMBO	0.577
MARANGANI	0.423
MARCAPATA	1
OCONGATE	0.401
OLLANTAYTAMBO	0.256
PAUCARTAMBO	0.544
PISAC	0.213
PITUMARCA	0.488
QUIQUIJANA	0.199
SAN PABLO	0.201
SAN SALVADOR	0.32
SANTO TOMAS	0.441
SICUANI	*0.178*

Table 8. Results of the Normalized Water Index (NWI) for each District – Department: LIMA

District	**NWI**
CARANIA	0.649
LARAOS	0.559
MIRAFLORES	0.623
TOMAS	0.552

Table 9. Results of the Normalized Water Index (NWI) for each District – Department: PUNO

District	**NWI**
AJOYANI	0.582
ANTAUTA	0.589
CORANI	0.35
CRUCERO	0.358
CUYOCUYO	0.353
MACUSANI	0.547
NUÑOA	0.377
POTONI	0.378
SANTA ROSA	0.342

3.2 Analysis of the climate change effects

The following table reports the values of the Reclassified Climate Change Index illustrated in the methodology. Values vary from 0.25 to 1. The higher is the value, the higher is the effect of the climate change as respect to the water availability.
The spatial distribution of the RCCI is reported in the Annex 2, Section 6.1.

Table 10. Values of the Reclassified Climate Change Index (RCCI) for each District – Department: APURIMAC

District	RCCI
ABANCAY	0.25
ANTABAMBA	0.5
CHUQUIBAMBILLA	0.25
HAQUIRA	0.25
HUAQUIRCA	0.5
LAMBRAMA	0.25
OROPESA	0.75
PATAYPAMPA	0.25
PROGRESO	0.25
TAMBURCO	1

Table 11. Values of the Reclassified Climate Change Index (RCCI) for each District – Department: AREQUIPA

District	RCCI
CAYARANI	0.75
CHACHAS	0.5
CHOCO	0.75
COTAHUASI	1
HUAYNACOTAS	0.5
ORCOPAMPA	0.75
PAMPAMARCA	0.5
PUYCA	0.75
SALAMANCA	0.75
SAN ANTONIO DE CHUCA	0.5
SAN JUAN DE TARUCANI	0.5
YANQUE	0.5

Table 12. Values of the Reclassified Climate Change Index (RCCI) for each District – Department: CUSCO

District	RCCI
ACOMAYO	0.25
CALCA	0.75
CCARHUAYO	1
CHALLABAMBA	0.5
CHECACUPE	0.75
CUSIPATA	0.75
HUAROCONDO	1

LAMAY	0.25
LARES	1
LAYO	0.25
LIMATAMBO	0.75
MARANGANI	0.25
MARCAPATA	1
OCONGATE	1
OLLANTAYTAMBO	0.75
PAUCARTAMBO	0.25
PISAC	0.25
PITUMARCA	0.5
QUIQUIJANA	0.25
SAN PABLO	0.5
SAN SALVADOR	0.5
SANTO TOMAS	0.75
SICUANI	0.25

Table 13. Values of the Reclassified Climate Change Index (RCCI) for each District – Department: LIMA

District	RCCI
CARANIA	1
LARAOS	1
MIRAFLORES	1
TOMAS	0.5

Table 14. Values of the Reclassified Climate Change Index (RCCI) for each District – Department: PUNO

District	RCCI
AJOYANI	1
ANTAUTA	0.25
CORANI	0.75
CRUCERO	1
CUYOCUYO	1
MACUSANI	1
NUÑOA	0.75
POTONI	0.25
SANTA ROSA	0.5

3.3 Combined Current Status and Climate Change Index

The following table reports the values of the combined Current Status and Climate Change Index illustrated in the methodology both as absolute (CI) and Reclassified (RCI) values. Values of RCI vary from 0.25 to 1. The higher is the value, the higher is the combined effect of the climate change and current water usages as respect to the water availability.
The spatial distribution of the CI is reported in the Annex 2, Section 6.1.

Table 15. Values of the absolute (CI) and Reclassified (RCI) values of the combined current and Climate Change Index – Department: APURIMAC

District	CI	RCI
ABANCAY	0.057	0.25
ANTABAMBA	0.286	0.75
CHUQUIBAMBILLA	0.11	0.25
HAQUIRA	0.053	0.25
HUAQUIRCA	0.262	0.75
LAMBRAMA	0.053	0.25
OROPESA	0.443	1
PATAYPAMPA	0.125	0.5
PROGRESO	0.12	0.25
TAMBURCO	0.217	0.75

Table 16. Values of the absolute (CI) and Reclassified (RCI) values of the combined current and Climate Change Index – Department: AREQUIPA

District	CI	RCI
CAYARANI	0.33	0.75
CHACHAS	0.206	0.5
CHOCO	0.269	0.75
COTAHUASI	0.521	1
HUAYNACOTAS	0.31	0.75
ORCOPAMPA	0.31	0.75
PAMPAMARCA	0.316	0.75
PUYCA	0.505	1
SALAMANCA	0.581	1
SAN ANTONIO DE CHUCA	0.21	0.5
SAN JUAN DE TARUCANI	0.169	0.5
YANQUE	0.195	0.5

Table 17. Values of the absolute (CI) and Reclassified (RCI) values of the combined current and Climate Change Index – Department: CUSCO

District	CI	RCI
ACOMAYO	0.051	0.25
CALCA	0.201	0.5
CCARHUAYO	0.648	1
CHALLABAMBA	0.125	0.5
CHECACUPE	0.183	0.5
CUSIPATA	0.17	0.5
HUAROCONDO	0.239	0.75

LAMAY	0.092	0.25
LARES	0.312	0.75
LAYO	0.105	0.25
LIMATAMBO	0.433	1
MARANGANI	0.106	0.25
MARCAPATA	1	1
OCONGATE	0.401	1
OLLANTAYTAMBO	0.192	0.5
PAUCARTAMBO	0.136	0.5
PISAC	0.053	0.25
PITUMARCA	0.244	0.75
QUIQUIJANA	0.05	0.25
SAN PABLO	0.101	0.25
SAN SALVADOR	0.16	0.5
SANTO TOMAS	0.331	1
SICUANI	0.044	0.25

Table 18. Values of the absolute (CI) and Reclassified (RCI) values of the combined current and Climate Change Index – Department: LIMA

District	CI	RCI
CARANIA	0.649	1
LARAOS	0.559	1
MIRAFLORES	0.623	1
TOMAS	0.276	0.75

Table 19. Values of the absolute (CI) and Reclassified (RCI) values of the combined current and Climate Change Index – Department: PUNO

District	CI	RCI
AJOYANI	0.582	1
ANTAUTA	0.147	0.5
CORANI	0.263	0.75
CRUCERO	0.358	1
CUYOCUYO	0.353	1
MACUSANI	0.547	1
NUÑOA	0.283	0.75
POTONI	0.094	0.25
SANTA ROSA	0.171	0.5

3.4 EbA Suitability

The following tables report the values of the EbA Suitability Index values for each district and each EbA. Values vary from 0 to 1. The higher is the value, the higher is the suitability of the EbA for the specific district.

The spatial distribution of the EbA suitability indexes is reported in the Annex 2, Section 6.2.

Table 20. Values of the EBA Suitability Index for each District for the 10 EbA – Department: APURIMAC

District	EbA									
	1	2	3	4	5	6	7	8	9	10
ABANCAY	0.013	0.009	0.158	0.545	0.179	0.072	1	0	0.159	0.103
ANTABAMBA	0.095	0.009	0.194	0.187	0.24	0.288	0.158	0	0	0.19
CHUQUIBAMBILLA	0.029	0.013	0.248	0.336	0.215	0.228	0.351	0	0	0.652
HAQUIRA	0.033	0.04	0.273	0.615	0.211	0.245	0.85	0	0	0.519
HUAQUIRCA	0.041	0.006	0.146	0.177	0.153	0.2	0.178	0	0	0.389
LAMBRAMA	0.039	0.03	0.171	0.239	0.199	0.19	0.446	0	0.008	0.808
OROPESA	0.313	0.133	0.297	0.045	0.489	0.626	0.067	0	0	0.218
PATAYPAMPA	0.023	0.005	0.073	0.075	0.071	0.092	0.068	0	0	0.061
PROGRESO	0.02	0.004	0.119	0.041	0.119	0.152	0.061	0	0	0.024
TAMBURCO	0.002	0.001	0.038	0.118	0.034	0.016	0.195	0	0.158	0.081

Table 21. Values of the EBA Suitability Index for each District for the 10 EbA – Department: AREQUIPA

District	EbA									
	1	2	3	4	5	6	7	8	9	10
CAYARANI	0.407	0.135	0.545	0.137	0.129	0.889	0.133	0.152	0	0
CHACHAS	0.219	0.477	0.374	0.029	0.21	0.674	0.054	0.047	0.238	0.29
CHOCO	0.136	0.011	0.205	0.039	0.123	0.431	0.05	0.203	1	0.223
COTAHUASI	0.007	0.001	0.027	0.133	0.02	0	0.176	0.075	0	0.263
HUAYNACOTAS	0.193	0.041	0.024	0.064	0.2	0	0.117	0.082	0.005	0.427
ORCOPAMPA	0.169	0.067	0.191	0.073	0.053	0.418	0.11	0.149	0	0
PAMPAMARCA	0.229	0.004	0.019	0.119	0.108	0	0.188	0.044	0	0.402
PUYCA	0.444	0.236	0.022	0.043	0.262	0.003	0.087	0.108	0	0.543
SALAMANCA	0.185	0.057	0.021	0.091	0.121	0	0.121	0.077	0.089	0.282
SAN ANTONIO DE CHUCA	0.457	0.026	0.258	0	0.103	0.525	0	0.024	0.308	0
SAN JUAN DE TARUCANI	0.297	0.176	0.139	0.003	0.424	0.256	0.001	0.002	0	0
YANQUE	0.244	0.007	0.154	0.076	0.119	0.355	0.111	0.171	0.782	0.158

Table 22. Values of the EBA Suitability Index for each District for the 10 EbA – Department: CUSCO

District	EbA									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ACOMAYO	0.007	0.001	0.048	0.165	0.03	0.013	0.164	0.187	0	0.415
CALCA	0.009	0.021	0.056	0.26	0.087	0.025	0.261	0.108	0.058	0.502
CCARHUAYO	0.016	0.006	0.024	0.048	0.11	0.028	0.078	0.049	0	0.168
CHALLABAMBA	0.015	0.008	0.089	0.156	0.244	0.016	0.259	0.32	0	0.266
CHECACUPE	0.301	0.134	0.359	0.121	0.292	0.381	0.182	0.114	0	0.449
CUSIPATA	0.026	0.007	0.055	0.176	0.083	0.029	0.263	0.134	0	0.182
HUAROCONDO	0.009	0.002	0.079	0.289	0.048	0.017	0.477	0.3	0	0.193
LAMAY	0.005	0.004	0.026	0.093	0.02	0.012	0.13	0.072	0	0.354
LARES	0.038	0.059	0.058	0.063	0.298	0.098	0.057	0.124	0.038	0.902
LAYO	0.162	0.044	0.218	1	0.168	0.139	0.511	0.683	0	0.003
LIMATAMBO	0.017	0	0.09	0.257	0.14	0.012	0.478	0.49	0	0.333
MARANGANI	0.118	0.032	0.134	0.438	0.141	0.102	0.413	0.319	0	0.072
MARCAPATA	0.093	0.049	0.059	0.002	0.503	0.168	0.002	0.296	0	0.019
OCONGATE	0.248	0.161	0.257	0.996	0.219	0.236	0.546	0.496	0	0.027
OLLANTAYTAMBO	0.029	0.007	0.098	0.25	0.155	0.059	0.322	0.301	0.14	0.914
PAUCARTAMBO	0.016	0.004	0.134	0.245	0.507	0.029	0.549	1	0	1
PISAC	0.006	0.008	0.045	0.162	0.035	0.013	0.226	0.178	0.038	0.38
PITUMARCA	0.298	1	0.244	0.056	0.31	0.275	0.084	0.075	0	0.06
QUIQUIJANA	0.036	0.014	0.098	0.325	0.1	0.021	0.432	0.366	0	0.75
SAN PABLO	0.125	0.005	0.21	0.174	0.205	0.176	0.226	0.162	0	0.095
SAN SALVADOR	0.003	0.003	0.046	0.227	0.02	0.002	0.39	0.146	0.043	0.343
SANTO TOMAS	0.341	0.068	0.295	0.206	0.36	0.381	0.259	0.335	0	0.402
SICUANI	0.228	0.126	0.276	0.461	0.194	0.226	0.583	0.534	0	0.145

Table 23. Values of the EBA Suitability Index for each District for the 10 EbA – Department: LIMA

District	EbA									
	1	2	3	4	5	6	7	8	9	10
CARANIA	0.001	0.009	0.031	0.036	0.038	0.039	0.068	0.048	0.175	0.272
LARAOS	0.075	0.127	0.144	0.01	0.131	0.17	0.02	0.067	0.634	0.414
MIRAFLORES	0.014	0.027	0.058	0.025	0.069	0.084	0.045	0.032	0.068	0.272
TOMAS	0.023	0.057	0.188	0.003	0.154	0.196	0.006	0.004	0	0.065

Table 24. Values of the EBA Suitability Index for each District for the 10 EbA – Department: PUNA

District	EbA									
	1	2	3	4	5	6	7	8	9	10
AJOYANI	0.062	0.079	0.242	0	0.215	0.253	0	0	0	0
ANTAUTA	0.153	0.031	0.429	0.14	0.291	0.431	0.122	0.162	0	0.002
CORANI	0.219	0.064	0.1	0.003	0.319	0.106	0.003	0.004	0	0.007
CRUCERO	0.08	0.42	0.407	0.096	0.202	0.447	0.063	0.086	0	0
CUYOCUYO	0.046	0.166	0.027	0.021	0.164	0.045	0.041	0.08	0	0.278
MACUSANI	0.228	0.346	0.345	0.215	0.392	0.411	0.129	0.175	0	0
NUÑOA	1	0.117	1	0.481	1	1	0.419	0.631	0	0.003
POTONI	0.14	0.01	0.407	0.13	0.294	0.413	0.071	0.097	0	0
SANTA ROSA	0.327	0.011	0.308	0.945	0.317	0.207	0.685	0.941	0	0

3.5 EbA Impact

The following tables report the values of the EbA Impact Index values for each district and each EbA. Values vary from 0 to 1. The higher is the value, the higher is potential relative impact of the EbA as respect to the water usages and water availability of the district. Finally, the EbA Impact for each district and EbA are summarized in the following Figure, representing the matrix with the number of districts belonging to specific EbA Suitability and Water stress ranges. The spatial distribution of the EbA impact indexes is reported in the Annex 2, Section 6.3.

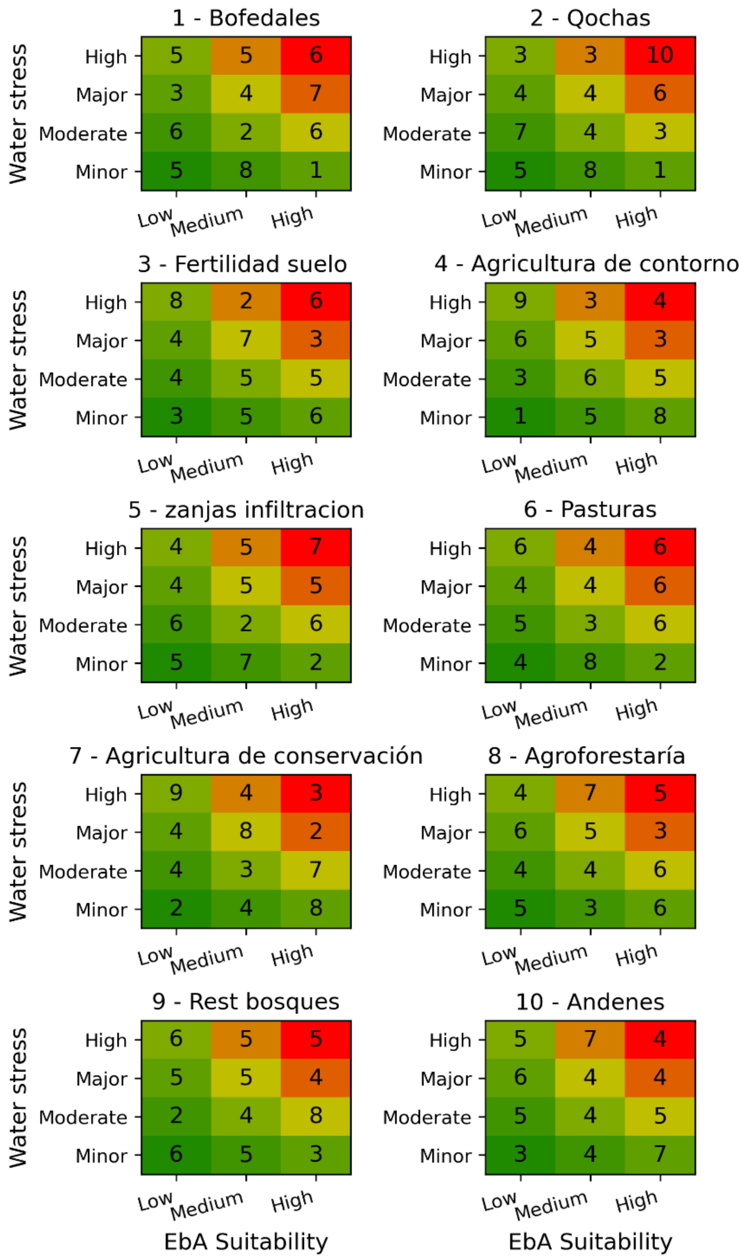

Figure 5. Summary of the EbA impact matrices for each of the 10 EbA measures. The numbers in each cell represent the number of districts belonging to specific Water stress and EbA Suitability categories

Table 25. Values of the EBA Impact Index for each District for the 10 EbA 1-5. – Department: APURIMAC

District	EbA									
	1	2	3	4	5	6	7	8	9	10
ABANCAY	0.003	0.002	0.032	0.078	0.02	0.014	0.262	0	0.026	0.021
ANTABAMBA	0.096	0.011	0.195	0.134	0.136	0.28	0.206	0	0	0.193
CHUQUIBAMBILLA	0.011	0.006	0.096	0.092	0.047	0.085	0.176	0	0	0.254
HAQUIRA	0.006	0.009	0.051	0.082	0.022	0.044	0.205	0	0	0.098
HUAQUIRCA	0.038	0.006	0.135	0.117	0.08	0.179	0.214	0	0	0.363
LAMBRAMA	0.007	0.007	0.032	0.032	0.021	0.034	0.107	0	0.001	0.152
OROPESA	0.491	0.242	0.465	0.05	0.432	0.946	0.136	0	0	0.344
PATAYPAMPA	0.01	0.003	0.032	0.023	0.018	0.039	0.039	0	0	0.027
PROGRESO	0.008	0.002	0.051	0.012	0.029	0.062	0.034	0	0	0.01
TAMBURCO	0.001	0.001	0.029	0.064	0.015	0.012	0.193	0	0.097	0.062

Table 26. Values of the EBA Impact Index for each District for the 10 EbA 1-5. – Department: AREQUIPA

District	EbA									
	1	2	3	4	5	6	7	8	9	10
CAYARANI	0.475	0.182	0.636	0.114	0.085	1	0.201	0.17	0	0
CHACHAS	0.16	0.403	0.273	0.015	0.086	0.474	0.051	0.033	0.138	0.213
CHOCO	0.13	0.012	0.195	0.026	0.066	0.395	0.062	0.185	0.759	0.214
COTAHUASI	0.012	0.001	0.049	0.174	0.021	0	0.418	0.133	0	0.488
HUAYNACOTAS	0.211	0.052	0.026	0.05	0.123	0	0.165	0.085	0.004	0.471
ORCOPAMPA	0.185	0.085	0.21	0.057	0.032	0.442	0.156	0.155	0	0
PAMPAMARCA	0.256	0.005	0.022	0.094	0.068	0	0.272	0.047	0	0.453
PUYCA	0.792	0.488	0.04	0.054	0.263	0.006	0.201	0.185	0	0.975
SALAMANCA	0.379	0.136	0.043	0.132	0.14	0.001	0.322	0.151	0.145	0.582
SAN ANTONIO DE CHUCA	0.339	0.022	0.191	0	0.043	0.375	0	0.017	0.182	0
SAN JUAN DE TARUCANI	0.177	0.122	0.083	0.001	0.143	0.148	0.001	0.001	0	0
YANQUE	0.168	0.006	0.106	0.037	0.046	0.236	0.099	0.112	0.43	0.11

Table 27. Values of the EBA Impact Index for each District for the 10 EbA 1-5. – Department: CUSCO

District	EbA									
	1	2	3	4	5	6	7	8	9	10
ACOMAYO	0.001	0	0.009	0.021	0.003	0.002	0.038	0.032	0	0.075
CALCA	0.006	0.017	0.04	0.131	0.035	0.017	0.24	0.073	0.033	0.36
CCARHUAYO	0.036	0.017	0.056	0.078	0.142	0.063	0.232	0.107	0	0.387
CHALLABAMBA	0.007	0.004	0.039	0.049	0.061	0.007	0.148	0.135	0	0.119
CHECACUPE	0.195	0.1	0.232	0.056	0.106	0.238	0.152	0.071	0	0.293
CUSIPATA	0.016	0.005	0.033	0.075	0.028	0.017	0.205	0.077	0	0.11
HUAROCONDO	0.008	0.002	0.067	0.174	0.023	0.014	0.522	0.243	0	0.165
LAMAY	0.002	0.002	0.009	0.021	0.004	0.004	0.055	0.022	0	0.116
LARES	0.041	0.076	0.064	0.049	0.185	0.104	0.081	0.131	0.033	1
LAYO	0.06	0.019	0.081	0.263	0.035	0.05	0.245	0.242	0	0.001
LIMATAMBO	0.027	0	0.138	0.278	0.121	0.018	0.944	0.716	0	0.513
MARANGANI	0.044	0.014	0.05	0.116	0.03	0.037	0.199	0.114	0	0.027
MARCAPATA	0.33	0.203	0.208	0.005	1	0.571	0.008	1	0	0.067
OCONGATE	0.352	0.264	0.363	1	0.175	0.323	1	0.672	0	0.039
OLLANTAYTAMBO	0.019	0.006	0.066	0.12	0.059	0.039	0.282	0.195	0.076	0.624
PAUCARTAMBO	0.008	0.002	0.064	0.084	0.137	0.013	0.341	0.46	0	0.484
PISAC	0.001	0.002	0.009	0.022	0.004	0.002	0.055	0.032	0.006	0.072
PITUMARCA	0.257	1	0.21	0.034	0.151	0.229	0.094	0.061	0	0.052
QUIQUIJANA	0.006	0.003	0.017	0.041	0.01	0.004	0.099	0.062	0	0.133
SAN PABLO	0.045	0.002	0.075	0.044	0.041	0.06	0.104	0.055	0	0.034
SAN SALVADOR	0.002	0.002	0.026	0.091	0.006	0.001	0.286	0.079	0.019	0.195
SANTO TOMAS	0.398	0.093	0.345	0.171	0.237	0.429	0.391	0.374	0	0.473
SICUANI	0.036	0.023	0.043	0.051	0.017	0.034	0.118	0.08	0	0.023

Table 28. Values of the EBA Impact Index for each District for the 10 EbA 1-5. – Department: LIMA

District	EbA									
	1	2	3	4	5	6	7	8	9	10
CARANIA	0.003	0.024	0.072	0.059	0.049	0.087	0.201	0.105	0.321	0.627
LARAOS	0.149	0.291	0.286	0.014	0.146	0.323	0.052	0.126	1	0.824
MIRAFLORES	0.031	0.069	0.128	0.039	0.085	0.179	0.128	0.068	0.119	0.603
TOMAS	0.022	0.065	0.184	0.002	0.084	0.185	0.008	0.004	0	0.064

Table 29. Values of the EBA Impact Index for each District for the 10 EbA 1-5. – Department: PUNO

District	EbA									
	1	2	3	4	5	6	7	8	9	10
AJOYANI	0.127	0.188	0.498	0	0.248	0.503	0	0	0	0
ANTAUTA	0.08	0.019	0.223	0.052	0.085	0.216	0.082	0.081	0	0.001
CORANI	0.203	0.069	0.093	0.002	0.166	0.095	0.004	0.004	0	0.006
CRUCERO	0.102	0.617	0.515	0.086	0.144	0.546	0.104	0.104	0	0
CUYOCUYO	0.057	0.24	0.033	0.018	0.115	0.054	0.066	0.096	0	0.35
MACUSANI	0.441	0.775	0.667	0.295	0.427	0.766	0.322	0.323	0	0
NUÑOA	1	0.135	1	0.341	0.563	0.964	0.542	0.603	0	0.003
POTONI	0.047	0.004	0.136	0.031	0.055	0.133	0.031	0.031	0	0
SANTA ROSA	0.197	0.007	0.186	0.405	0.108	0.121	0.535	0.544	0	0

3.6 Summary of the results

Results should be interpreted as follows:

1. The Normalized Water Index (NWI) identifies the Districts that are more likely to be endangered by the water resources demand as respect to the water resources availability according to the current climate status. This means that districts with the higher NWI are the ones to pay more attention regarding the current water scarcity.
2. The Reclassified Climate Change Index (RCCI) identifies the Districts that are more likely to be endangered by the water resources demand as respect to the water resources availability according to the future climate projections (RCP 8.5, year 2050 scenario). This means that districts with the higher RCCI are the ones to pay more attention regarding the future water scarcity.
3. The Combined Current Status and Climate Change Index The Reclassified Climate Change Indexes (CI and RCI) identify the Districts that are more likely to be endangered by the water resources demand as respect to the water resources availability considering the current and the future climate projections. This means that districts with the higher CI and RCI are the ones to pay more attention regarding the current and future water scarcity.
4. The indexes of points 1,2 and 3 provide information on the current and future status of the water resources availability as respect to the water resources demand of the studied districts, therefore they should be interpreted as hazard metrics.
5. The 10 EbA Suitability indexes identify the districts that are more suitable for the implementation of the EbA measures according. The analyses were based on the report "EbA Measures for a resilient PUNA: A catalogue for the south high Andean Peru)". This means that districts with the higher EbA Suitability indexes are the ones where the EbA measure are more suitable.
6. The 10 EbA Impact indexes represent the summary and the main outcomes of this report, since they identify the districts that should be more positively impacted by the implementation of the EbA measures. In fact, these indexes considered the combined effect of water resources availability hazard and each EbA suitability. These indexes can provide a guidance for the choice and prioritizations of the EbA measures in the study area.

3.7 Recommendations on the use of the results for the EbA implementation

These EbA impact indexes can provide a guidance for the choice and prioritizations of the EbA measures in the study area. Note that this analysis provides numbers (indexes) that should be read as suggestions for the EbA implementation strategy,but cannot provide specific quantitative information on the hydrological benefits of the EbA. In fact, quantitative information should be supported by local information of water resources and also on the design of each EbA (extension, techniques, types of soils, etc.). Therefore, the results can be read as a way for prioritize more specific EbA implementation studies where field works and design of each EbA can provide quantitative benefits of EbA on the improvement of the water resources management. There are many guidelines providing best practices on such types of EbA, such as:

- The Global guidelines for peatland rewetting and restoration (Convention on Wetlands. (2021).
- Managing Lakes and reservoirs (North American Lake Management Society, 2001)
- Integrated soil fertility management (Ministry of Foreign Affairs, Nehterland,, 2000)
- Contour farming (NRCS, 2017)
- Infiltration ditches (Catrans, 2020)
- Sustainable Grassland Management (FAO, 2021)
- Conservation agriculture (FAO, 2019)
- Agroforesty (ICRAF, 2013)
- Forest restoration with native species (US EPA, 2002)
- Terrace restoration (Shouf Biosphere Reserve, 2020)

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5 Annex 1 - Tables

Table 30. Aggregated current status variables for each district. Department: APURIMAC

District	Area (km^2)	Annual average discharge (m^3/s)	Annual avg surface runoff (mm)	Annual average PET (mm)	Annual average precip (mm)	Snow Cover Extent (%)	Cropland Extent (%)	Pasture Extent (%)	Irrigated Area Extent (%)	Population Count (#)	Urban Extent (%)
ABANCAY	286.57	55.94	624.59	1300.69	792.03	1.00	5.60	43.44	2.00	61.80	2.40
ANTABAMBA	602.52	5.62	551.64	1031.71	770.72	2.32	2.76	48.30	0.66	1.54	0.00
CHUQUIBAMBILLA	425.41	4.54	591.26	1141.76	779.64	0.32	3.41	44.06	1.01	2.74	0.00
HAQUIRA	484.06	13.87	699.66	1181.57	818.58	0.20	6.79	40.37	0.78	10.79	0.34
HUAQUIRCA	350.74	6.19	572.95	1091.47	782.85	1.30	2.74	54.83	1.01	1.59	0.00
LAMBRAMA	525.59	22.52	597.19	1228.98	777.44	1.00	5.40	46.51	1.96	9.88	0.20
OROPESA	1170.60	8.87	625.16	1024.48	766.85	2.24	2.85	43.88	0.73	1.45	0.00
PATAYPAMPA	146.41	9.02	591.69	1118.96	781.23	0.90	3.20	45.71	1.19	3.32	0.00
PROGRESO	240.42	6.01	652.91	1172.49	794.31	0.90	5.07	37.42	0.65	3.47	0.00
TAMBURCO	54.55	7.18	632.62	1351.14	781.21	1.00	5.99	44.95	2.10	39.44	3.93

Table 31. Aggregated current status variables for each district. Department: AREQUIPA

District	Area (km^2)	Annual average discharge (m^3/s)	Annual avg surface runoff (mm)	Annual average PET (mm)	Annual average precip (mm)	Snow Cover Extent (%)	Cropland Extent (%)	Pasture Extent (%)	Irrigated Area Extent (%)	Population Count (#)	Urban Extent (%)
CAYARANI	1392.94	5.86	457.62	1006.94	697.08	1.02	3.02	48.98	0.05	1.67	0.00
CHACHAS	1195.72	6.90	408.19	998.52	694.08	1.42	3.06	49.23	0.67	2.93	0.00
CHOCO	902.95	21.62	288.94	1012.60	651.11	0.86	2.64	50.02	0.78	6.06	0.00
COTAHUASI	166.70	28.59	179.93	1030.14	684.26	1.71	2.68	36.82	1.57	7.46	0.00
HUAYNACOTAS	935.18	9.58	409.48	974.45	740.19	2.94	2.61	33.29	1.21	1.70	0.00
ORCOPAMPA	728.63	4.48	399.18	1000.21	688.35	1.21	3.16	46.70	0.60	2.51	0.00
PAMPAMARCA	787.61	4.68	304.21	1013.13	746.06	1.84	2.16	37.21	0.77	0.86	0.00
PUYCA	1503.41	6.20	441.11	958.76	720.72	2.86	3.41	37.08	0.37	0.82	0.00
SALAMANCA	1240.77	2.84	154.21	968.83	631.66	2.46	1.00	42.91	0.77	0.58	0.00
SAN ANTONIO DE CHUCA	1540.26	2.92	227.86	1000.64	571.08	0.01	3.56	55.51	0.29	0.58	0.00
SAN JUAN DE TARUCANI	2382.97	3.04	98.00	1014.01	472.60	0.24	0.50	45.96	1.27	2.53	0.00
YANQUE	1111.86	4.15	206.32	1018.26	527.82	0.57	1.53	53.96	2.68	1.44	0.00

Table 32. Aggregated current status variables for each district. Department: CUSCO

District	Area (km^2)	Annual average discharge (m^3/s)	Annual avg surface runoff (mm)	Annual average PET (mm)	Annual average precip (mm)	Snow Cover Extent (%)	Cropland Extent (%)	Pasture Extent (%)	Irrigated Area Extent (%)	Population Count (#)	Urban Extent (%)
ACOMAYO	141.30	3.80	658.53	1249.55	786.13	0.02	9.01	41.92	3.06	6.26	0.05
CALCA	312.44	71.97	684.14	1163.16	756.14	1.00	4.01	38.00	1.52	296.19	1.50
CCARHUAYO	303.33	12.86	1120.00	1124.86	754.59	2.98	3.46	35.33	0.49	6.09	0.00
CHALLABAMBA	714.10	46.89	755.87	1219.73	696.66	1.63	5.38	36.10	1.05	43.67	0.00
CHECACUPE	936.93	25.31	1098.46	1003.37	793.63	5.29	6.85	53.90	2.07	16.56	0.08
CUSIPATA	242.52	40.47	749.56	1123.73	783.62	1.40	6.03	43.54	1.37	44.70	2.30
HUAROCONDO	220.30	12.81	733.01	1250.78	741.26	0.57	6.45	33.59	5.89	60.37	2.94
LAMAY	95.49	134.37	659.51	1159.84	769.01	1.95	5.93	44.88	1.99	554.01	1.97
LARES	731.86	7.85	775.61	1212.61	736.14	0.01	3.68	28.61	1.15	5.27	0.01
LAYO	425.82	3.80	607.64	1136.20	798.18	0.30	4.65	44.40	1.83	2.89	0.00
LIMATAMBO	505.96	142.59	714.51	1251.83	791.50	1.57	4.54	38.71	1.41	86.01	0.00
MARANGANI	438.74	6.29	644.44	1089.77	790.81	1.22	3.13	52.54	0.94	10.38	0.00
MARCAPATA	1300.21	22.42	2147.66	1105.26	791.24	3.82	4.32	41.00	0.00	0.98	0.00
OCONGATE	947.81	8.64	1111.76	1074.19	776.06	9.09	8.91	39.70	2.32	4.09	0.01
OLLANTAYTAMBO	579.18	76.74	789.53	1182.76	765.83	1.18	4.19	39.64	2.21	304.01	1.03
PAUCARTAMBO	1091.14	19.13	1146.27	1297.81	713.03	0.92	4.52	30.55	1.03	13.37	0.00
PISAC	147.71	26.65	659.42	1215.18	723.41	0.35	4.37	46.04	2.81	100.75	0.36
PITUMARCA	1091.07	7.86	1094.09	996.36	797.04	7.67	4.88	42.82	1.36	1.98	0.13
QUIQUIJANA	364.18	66.52	718.41	1163.44	776.72	1.36	8.01	46.56	1.90	76.90	0.55
SAN PABLO	522.96	24.62	843.48	1037.56	789.73	2.91	5.86	60.00	1.29	15.33	0.17
SAN SALVADOR	128.05	136.13	650.37	1154.47	773.08	1.97	6.02	45.89	1.99	494.09	2.08
SANTO TOMAS	1904.78	14.25	685.00	1028.74	759.81	1.47	3.40	46.36	0.00	6.17	0.00
SICUANI	646.41	15.18	714.09	1096.75	787.99	1.57	4.61	62.33	1.68	24.81	0.52

Table 33. Aggregated current status variables for each district. Department: LIMA

District	Area (km^2)	Annual average discharge (m^3/s)	Annual avg surface runoff (mm)	Annual average PET (mm)	Annual average precip (mm)	Snow Cover Extent (%)	Cropland Extent (%)	Pasture Extent (%)	Irrigated Area Extent (%)	Population Count (#)	Urban Extent (%)
CARANIA	122.08	40.29	523.80	925.94	889.29	0.00	2.09	45.11	1.00	6.24	0.00
LARAOS	409.61	5.90	591.77	914.20	884.47	0.33	2.83	49.97	2.73	0.88	0.00
MIRAFLORES	201.93	8.27	573.09	891.18	915.40	0.37	1.78	46.01	0.45	1.18	0.00
TOMAS	291.59	4.99	676.09	936.62	900.89	0.03	2.74	47.71	0.30	1.01	0.00

Table 34. Aggregated current status variables for each district. Department: PUNO

District	Area (km^2)	Annual average discharge (m^3/s)	Annual avg surface runoff (mm)	Annual average PET (mm)	Annual average precip (mm)	Snow Cover Extent (%)	Cropland Extent (%)	Pasture Extent (%)	Irrigated Area Extent (%)	Population Count (#)	Urban Extent (%)
AJOYANI	425.99	5.42	1077.68	1046.96	746.58	0.00	3.97	75.07	0.00	1.05	0.00
ANTAUTA	654.88	4.77	698.24	1104.32	722.51	0.01	6.26	79.50	0.00	1.74	0.00
CORANI	886.43	20.25	1811.05	1000.85	780.36	3.41	7.77	60.90	0.01	2.05	0.00
CRUCERO	854.72	16.21	585.15	1021.88	704.87	0.00	7.40	69.82	0.00	23.30	0.19
CUYOCUYO	511.66	3.46	442.47	1037.55	701.96	0.00	5.03	61.32	0.00	4.10	0.22
MACUSANI	1016.40	20.05	1492.11	1042.64	755.86	0.22	14.77	74.19	0.00	5.69	0.36
NUÑOA	2200.80	5.66	688.01	1075.55	755.59	1.13	7.95	78.47	0.37	2.18	0.00
POTONI	621.57	17.09	570.94	1065.99	708.98	0.00	9.98	76.70	0.00	20.24	0.07
SANTA ROSA	803.75	6.71	506.65	1129.25	767.78	0.69	6.50	67.65	0.18	3.95	0.00

Table 35. Aggregated climate change variables for each district. Department: APURIMAC

District	Area (km^2)	Glaciers elevation changes between 2000 and 2016 (mm)	Precipitation Change (%)
ABANCAY	286.57	0	11.25
ANTABAMBA	602.52	0.00	7.50
CHUQUIBAMBILLA	425.41	0.00	11.25
HAQUIRA	484.06	0.00	11.25
HUAQUIRCA	350.74	0.00	7.50
LAMBRAMA	525.59	0.00	11.25
OROPESA	1170.60	-2504.50	7.50
PATAYPAMPA	146.41	0.00	11.25
PROGRESO	240.42	0.00	11.25
TAMBURCO	54.55	-11588.00	11.25

Table 36. Aggregated climate change variables for each district. Department: AREQUIPA

District	Area (km^2)	Glaciers elevation changes between 2000 and 2016 (mm)	Precipitation Change (%)
CAYARANI	1392.94	-3673.00	0.00
CHACHAS	1195.72	-447.25	-11.25
CHOCO	902.95	-3840.00	-11.25
COTAHUASI	166.70	-18120.00	-7.50
HUAYNACOTAS	935.18	0.00	-7.50
ORCOPAMPA	728.63	-4100.00	0.00
PAMPAMARCA	787.61	0.00	-7.50
PUYCA	1503.41	-6274.67	0.00
SALAMANCA	1240.77	-5445.78	-7.50

SAN ANTONIO DE CHUCA	1540.26	0.00	-7.50
SAN JUAN DE TARUCANI	2382.97	0.00	-7.50
YANQUE	1111.86	0.00	-7.50

Table 37. Aggregated climate change variables for each district. Department: CUSCO

District	Area (km^2)	Glaciers elevation changes between 2000 and 2016 (mm)	Precipitation Change (%)
ACOMAYO	141.30	0.00	18.75
CALCA	312.44	-3609.33	11.25
CCARHUAYO	303.33	-8045.17	7.50
CHALLABAMBA	714.10	0.00	11.25
CHECACUPE	936.93	-3392.56	18.75
CUSIPATA	242.52	-7376.00	18.75
HUAROCONDO	220.30	-12094.00	11.25
LAMAY	95.49	0.00	11.25
LARES	731.86	-16049.83	11.25
LAYO	425.82	0.00	15.00
LIMATAMBO	505.96	-4323.40	11.25
MARANGANI	438.74	0.00	15.00
MARCAPATA	1300.21	-8996.89	18.75
OCONGATE	947.81	-8735.32	18.75
OLLANTAYTAMBO	579.18	-6888.17	11.25
PAUCARTAMBO	1091.14	0.00	11.25
PISAC	147.71	0.00	11.25
PITUMARCA	1091.07	-1088.74	18.75
QUIQUIJANA	364.18	0.00	18.75
SAN PABLO	522.96	-2149.60	18.75
SAN SALVADOR	128.05	0.00	11.25
SANTO TOMAS	1904.78	-5778.67	0.00
SICUANI	646.41	0.00	15.00

Table 38. Aggregated climate change variables for each district. Department: LIMA

District	Area (km^2)	Glaciers elevation changes between 2000 and 2016 (mm)	Precipitation Change (%)
CARANIA	122.08	-8164.00	0.00
LARAOS	409.61	-14789.00	3.75
MIRAFLORES	201.93	-8201.23	3.75
TOMAS	291.59	0.00	3.75

Table 39. Aggregated climate change variables for each district. Department: PUNO

District	Area (km^2)	Glaciers elevation changes between 2000 and 2016 (mm)	Precipitation Change (%)
AJOYANI	425.99	-11607.75	18.75
ANTAUTA	654.88	0.00	18.75
CORANI	886.43	-3555.22	18.75
CRUCERO	854.72	-12730.62	0.00
CUYOCUYO	511.66	-8762.00	0.00
MACUSANI	1016.40	-13068.85	18.75
NUÑOA	2200.80	-5136.42	18.75
POTONI	621.57	0.00	18.75
SANTA ROSA	803.75	0.00	11.25

Table 40. Weights assigned to each variable of the current status and climate change analysis

Variables	Weights
Annual average discharge	1
Annual average land surface runoff	1
Annual average potential evapotransipration	0.25
Annual average precipitation	1
Sum of reservoir volume	1
Snow Cover Extent	1
Cropland Extent	1
Pasture Extent	0.75
Irrigated Area Extent (Equipped)	1
Population Count	0.75
Urban Extent	0.5
Glacier extent	1
Precipitation change	1

6 Annex 2 – Figures

6.1 Climate related variables maps

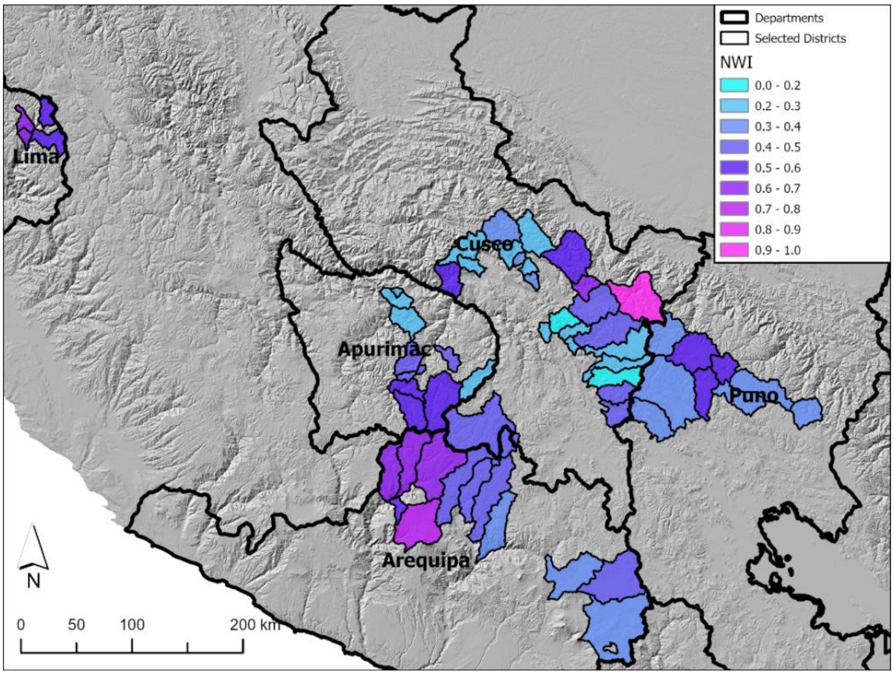

Figure 6. Spatial distribution of the Normalized Water index (NWI – Current hydrological status) for the selected districts in the Puna Region

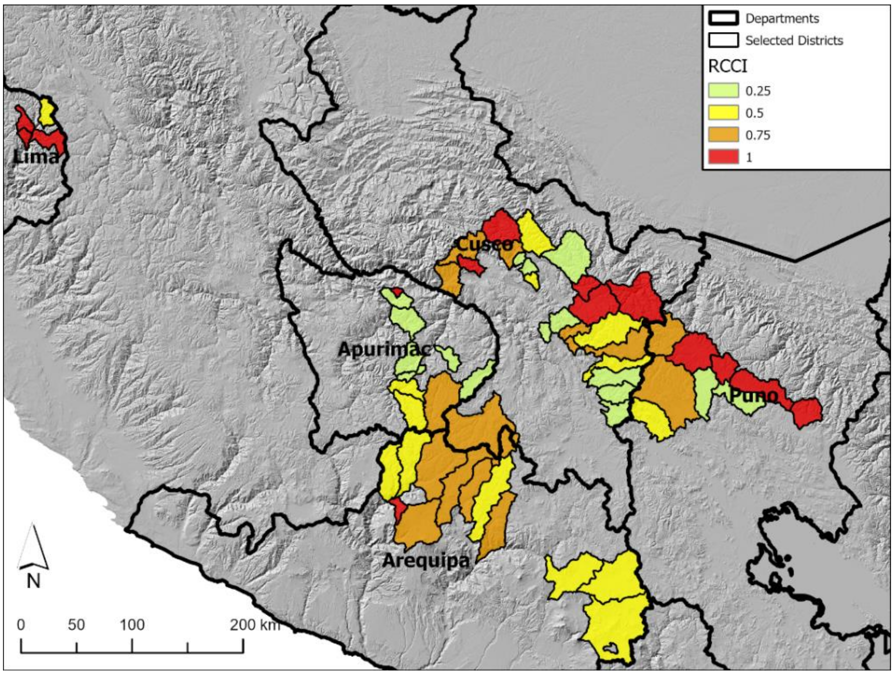

Figure 7. Spatial distribution of the Reclassified Climate Change Index (RCCI – Current hydrological status) for the selected districts in the Puna Region

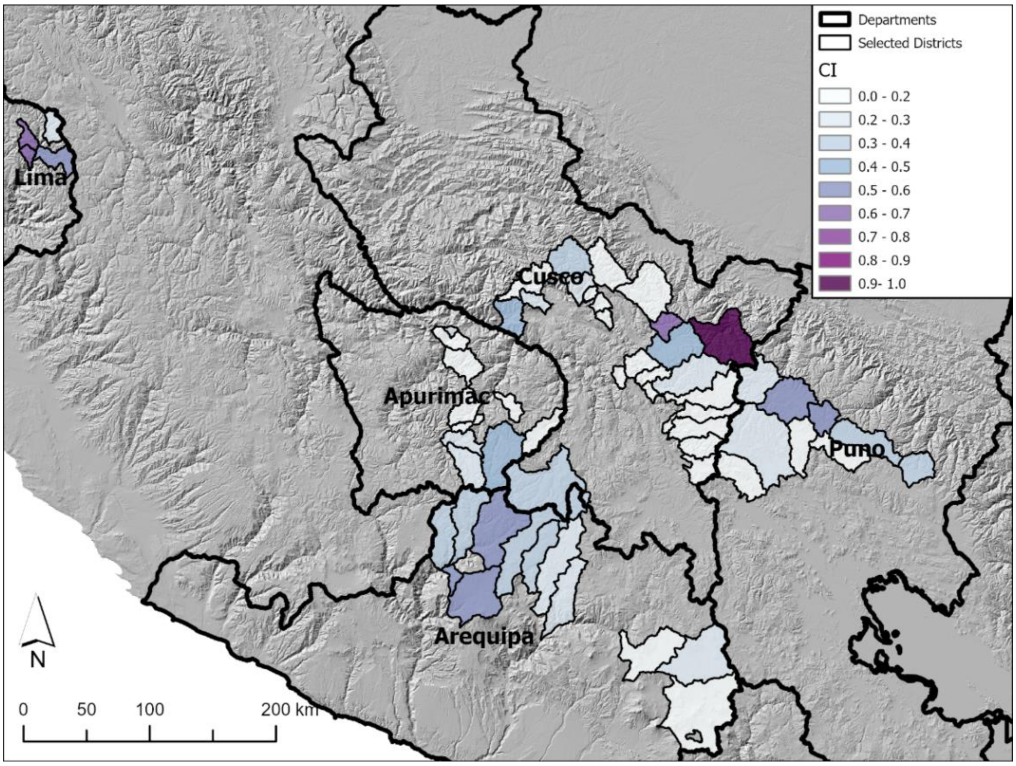

Figure 8. Spatial distribution of the Combined Current Status and Climate Change Index (CI) for the selected districts in the Puna Region

6.2 EbA suitability maps

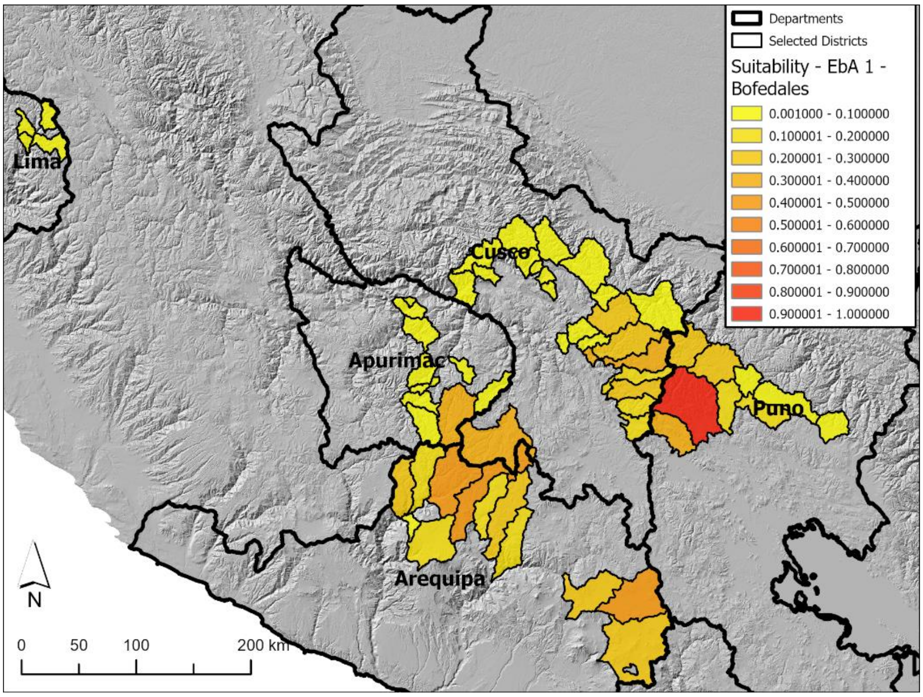

Figure 9. Spatial distribution of the EbA 1 (Bofedales) suitability for the selected districts in the Puna Region

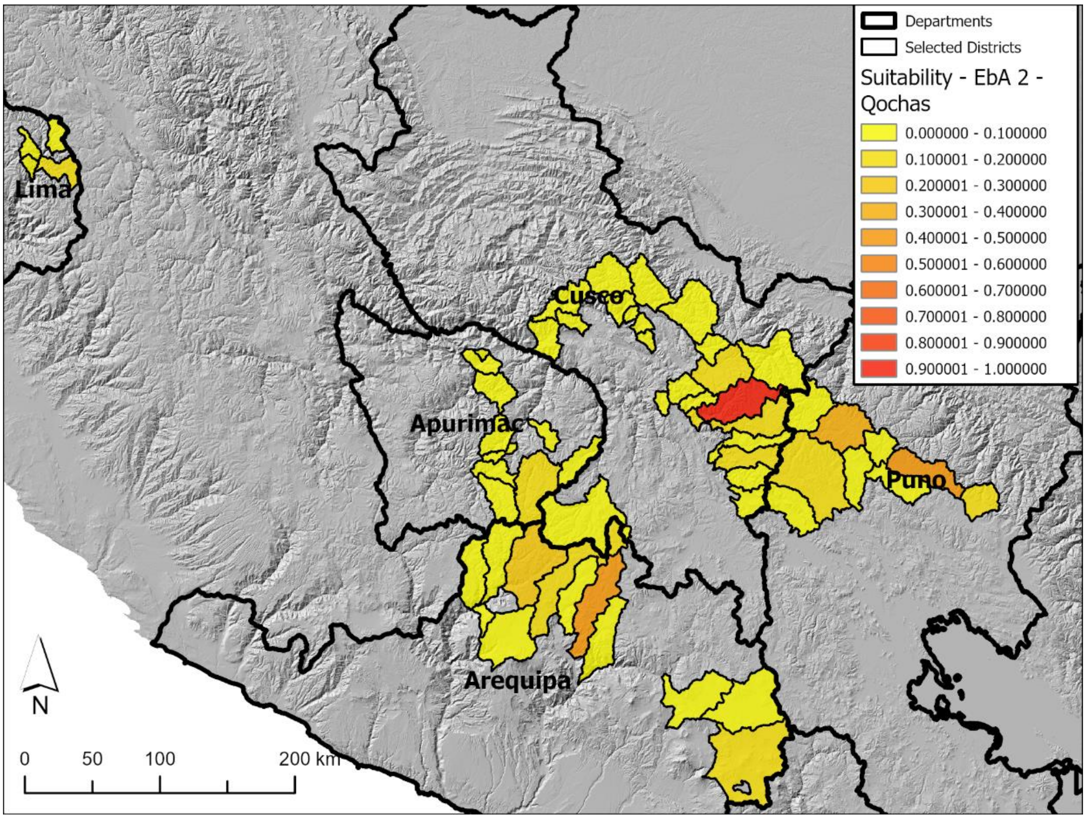

Figure 10. Spatial distribution of the EbA 2 (Qochas) suitability for the selected districts in the Puna Region

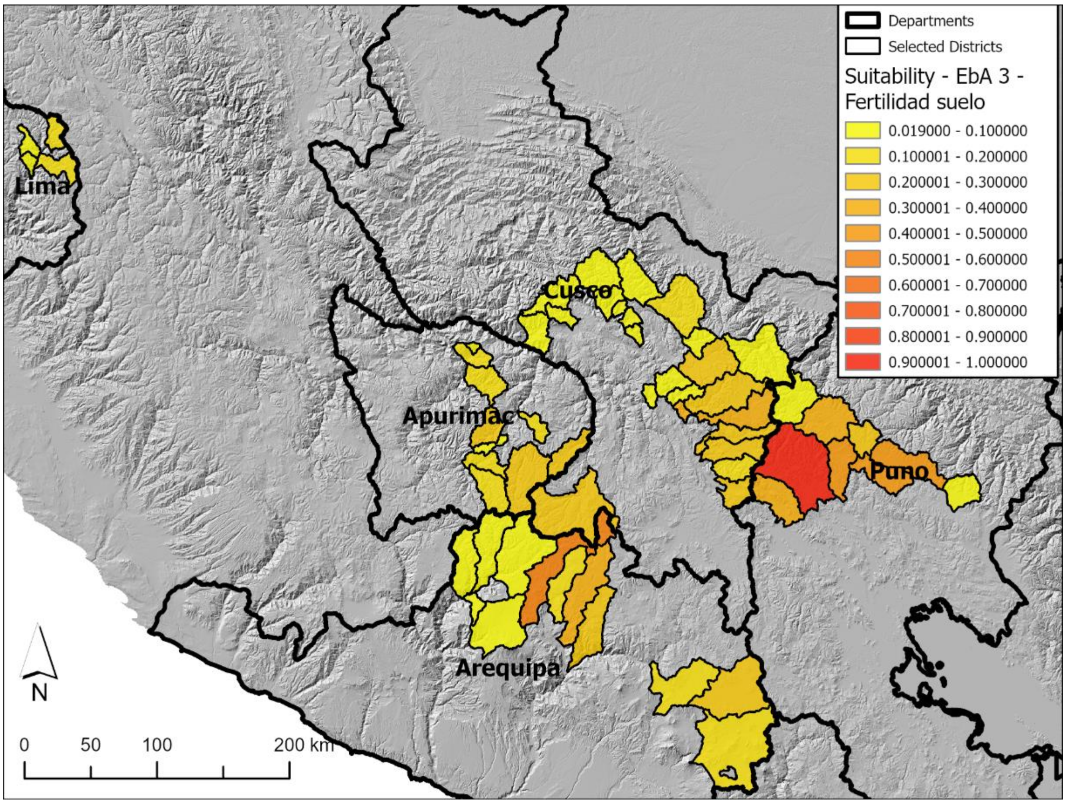

Figure 11. Spatial distribution of the EbA 3 (Fertilidad suelo) suitability for the selected districts in the Puna Region

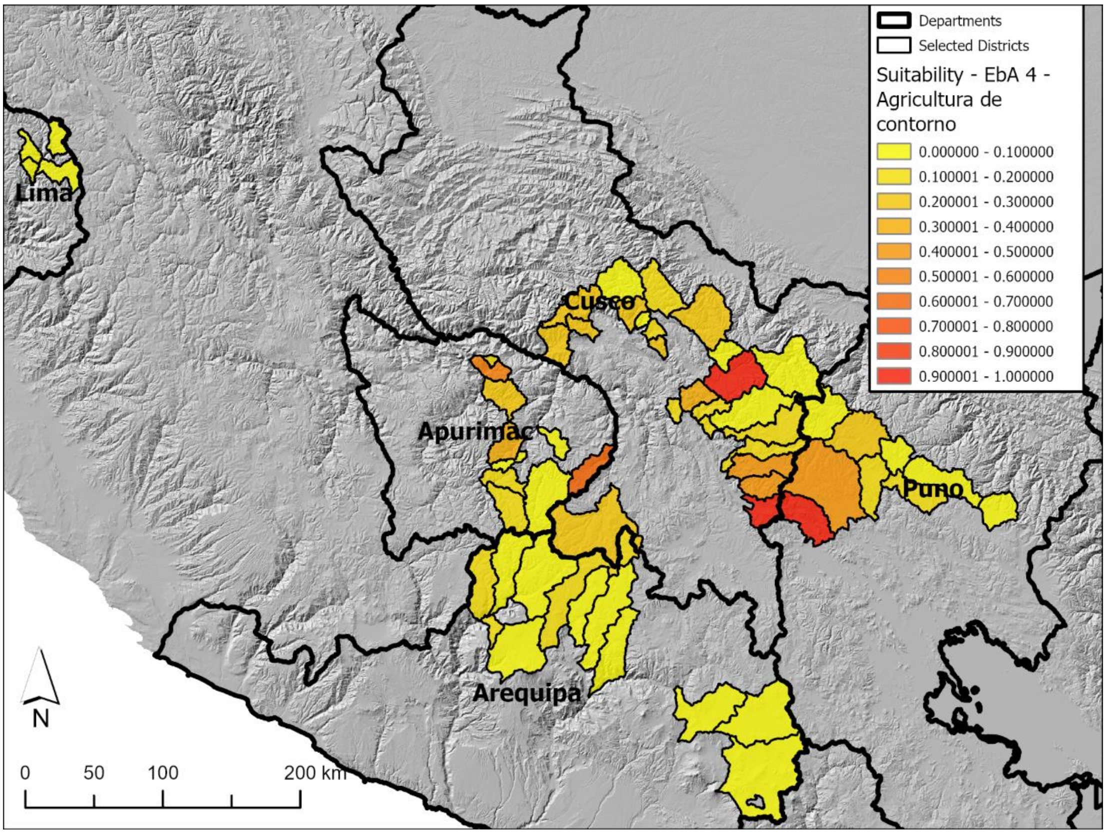

Figure 12. Spatial distribution of the EbA 4 (Agricultura de contorno) suitability for the selected districts in the Puna Region

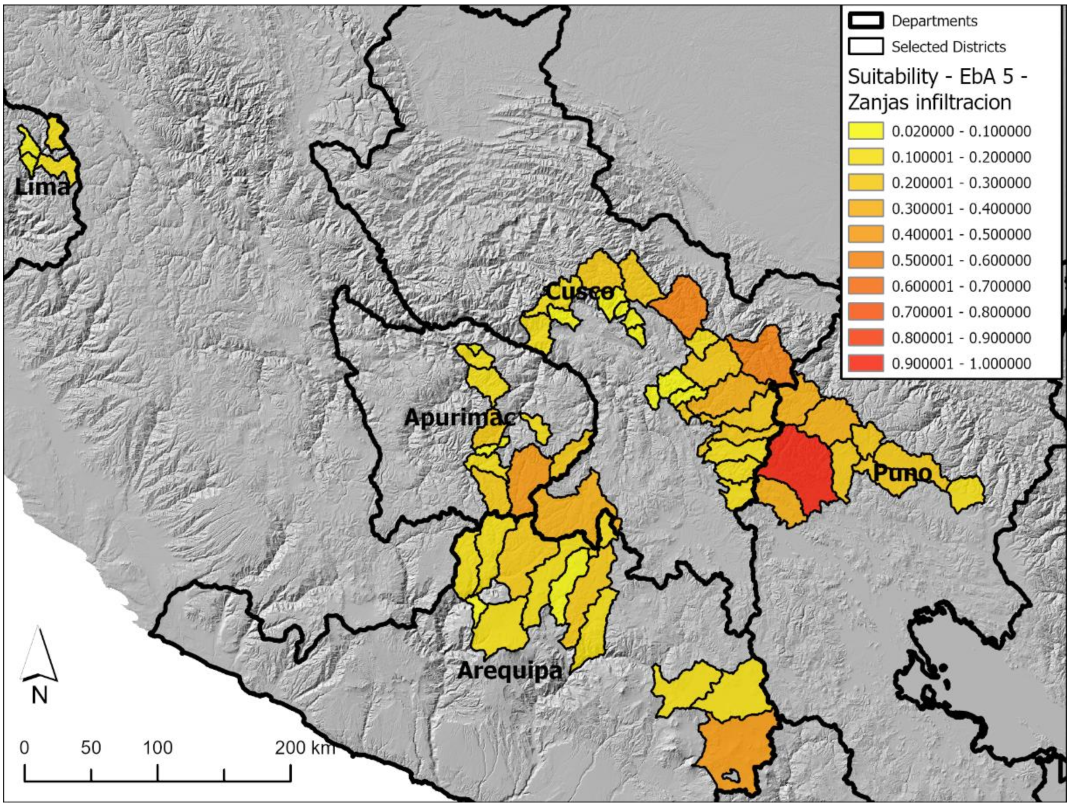

Figure 13. Spatial distribution of the EbA 5 (zanjas infiltracion) suitability for the selected districts in the Puna Region

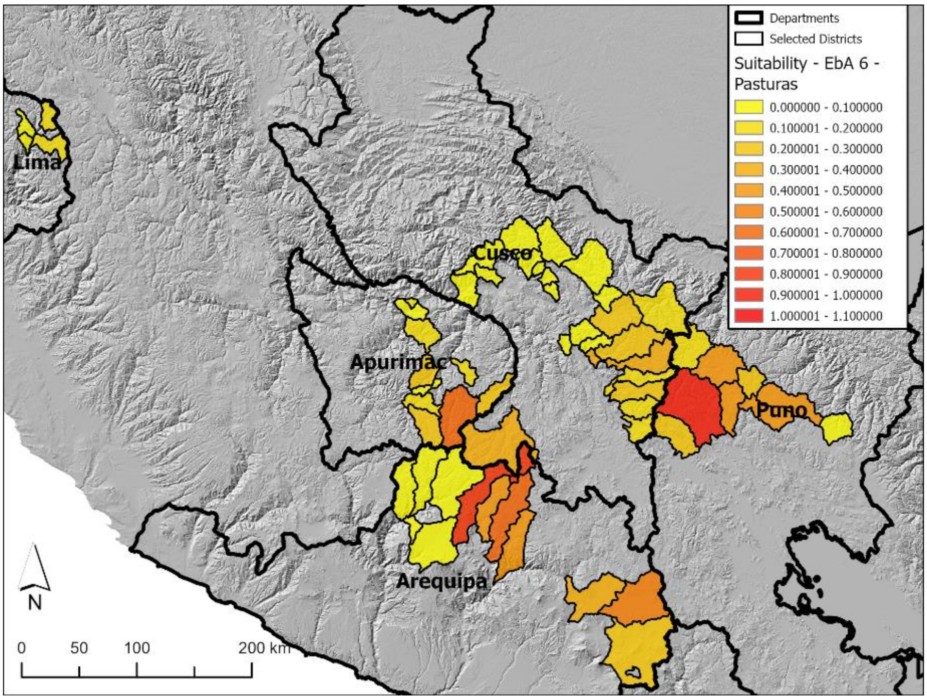

Figure 14. Spatial distribution of the EbA 6 (Pasturas) suitability for the selected districts in the Puna Region

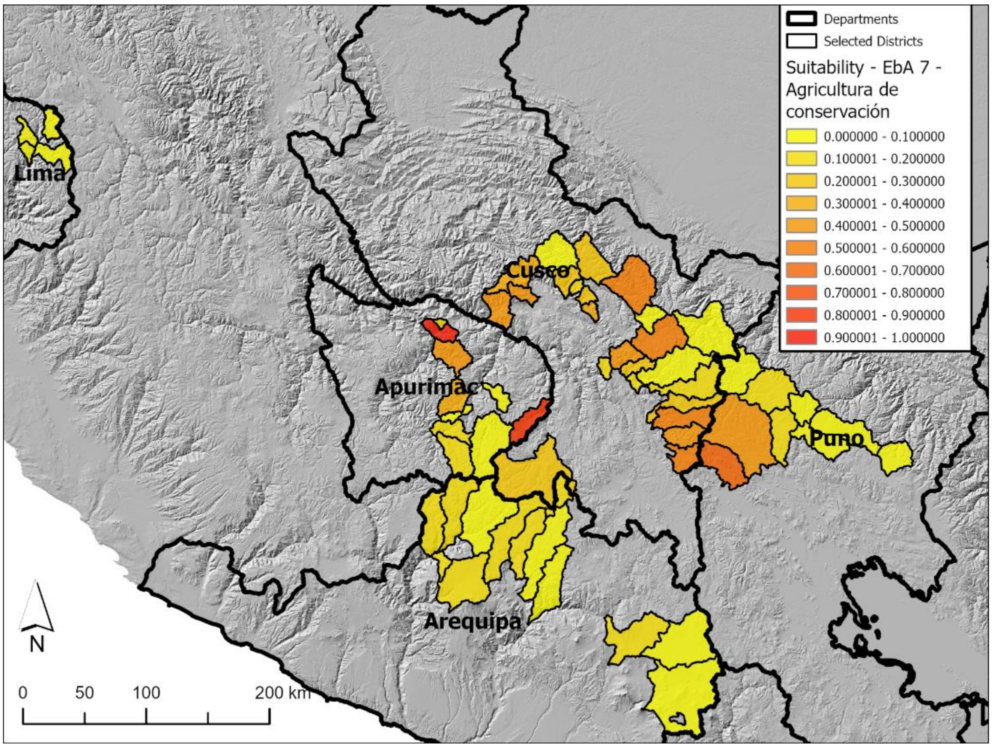

Figure 15. Spatial distribution of the EbA 7 (Agricultura de conservación) suitability for the selected districts in the Puna Region

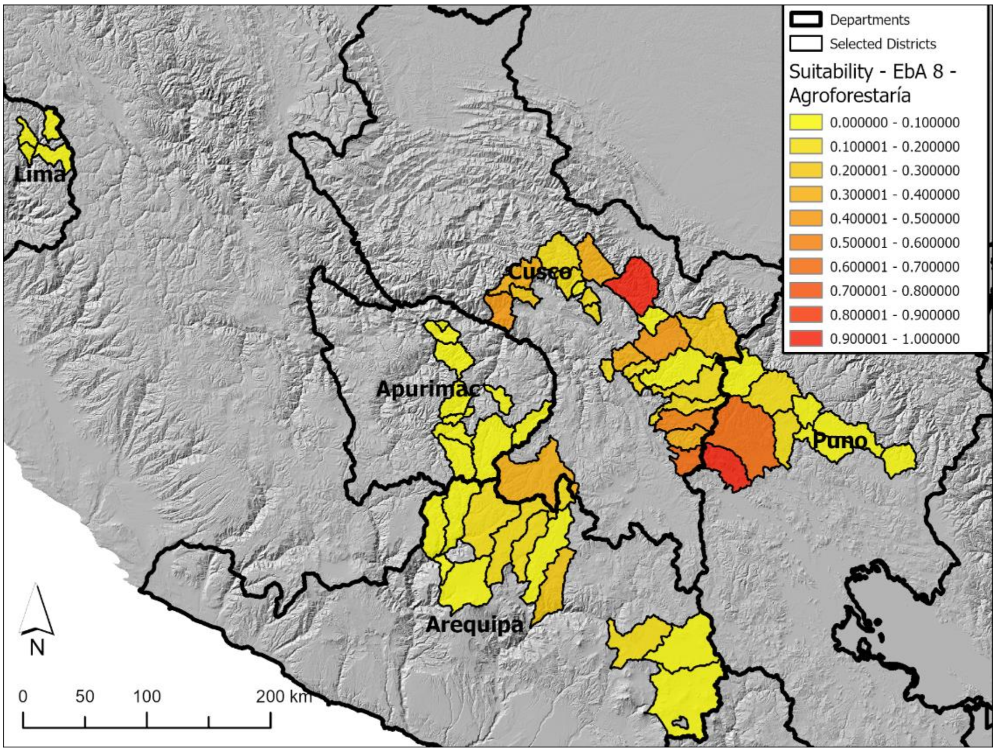

Figure 16. Spatial distribution of the EbA 8 (Agroforestaría) suitability for the selected districts in the Puna Region

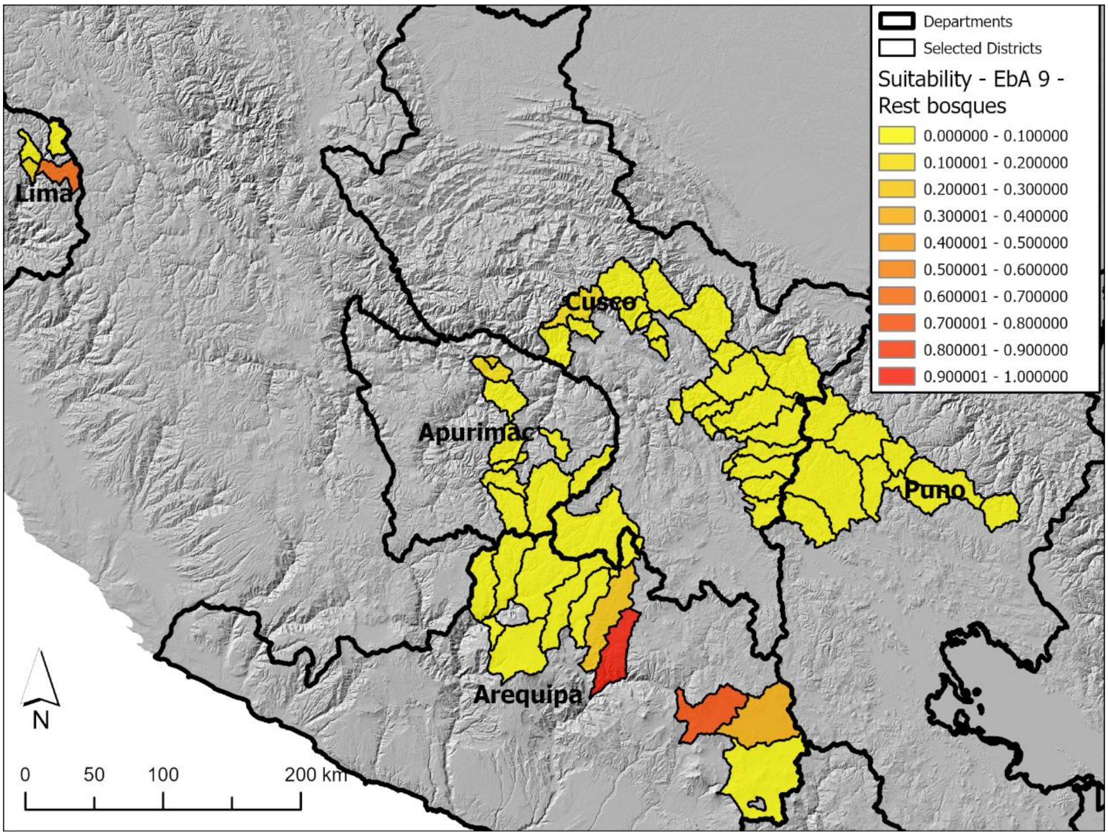

Figure 17. Spatial distribution of the EbA 9 (Rest bosques) suitability for the selected districts in the Puna Region

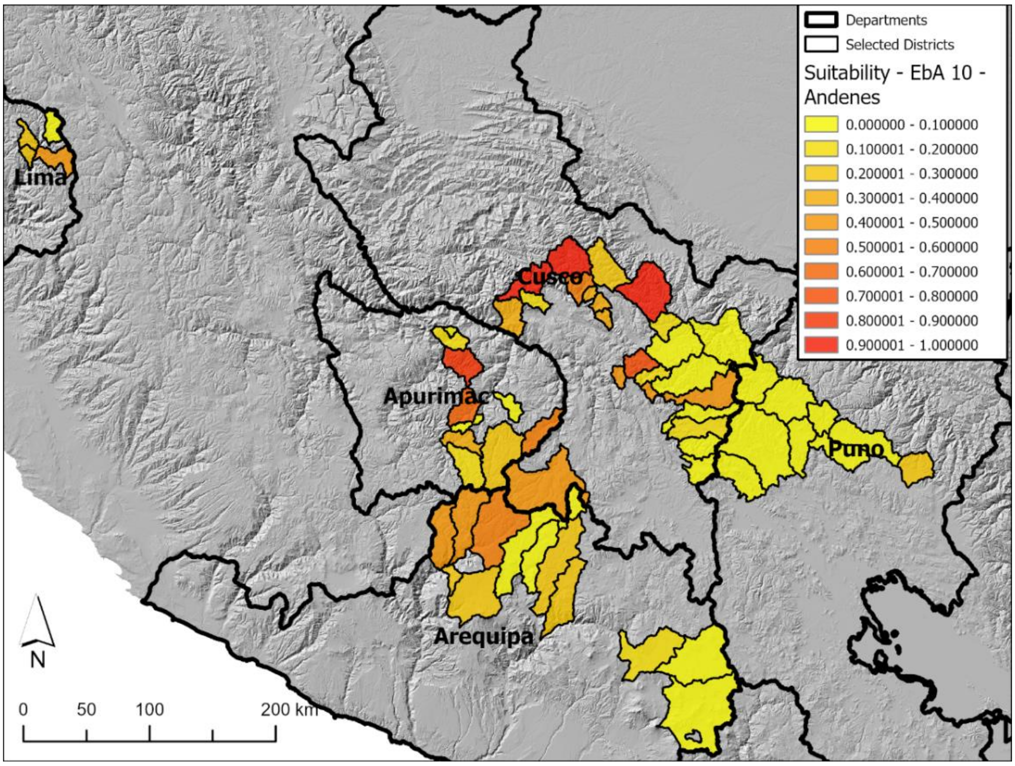

Figure 18. Spatial distribution of the EbA 10 (Andenes) suitability for the selected districts in the Puna Region

6.3 EbA impact maps

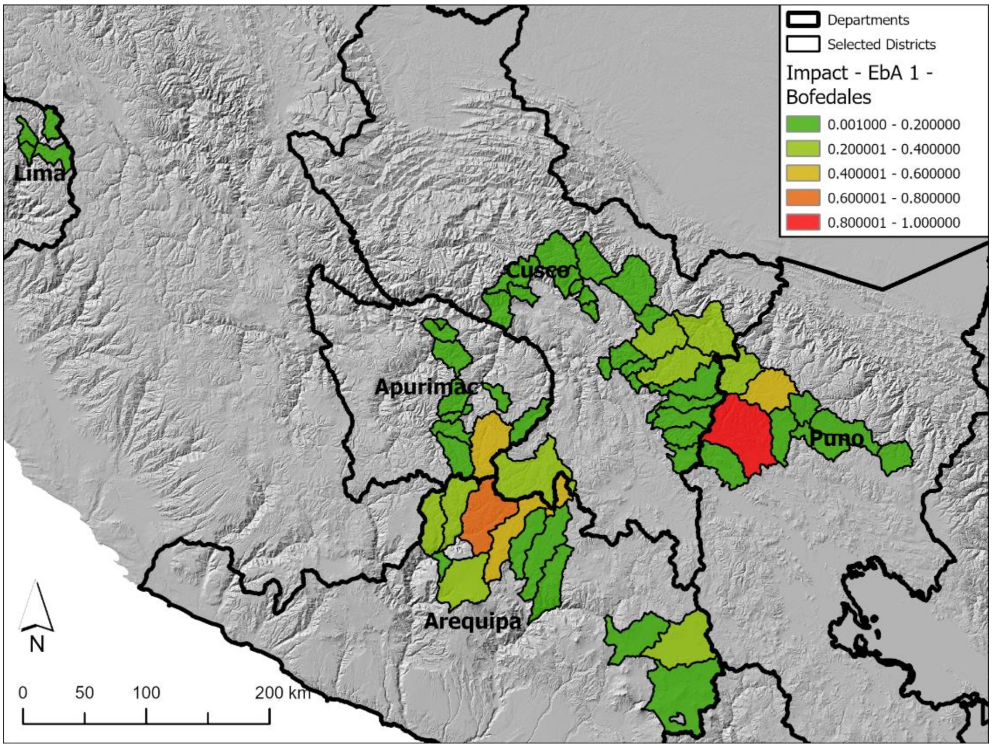

Figure 19. Spatial distribution of the EbA 1 (Bofedales) impact for the selected districts in the Puna Region

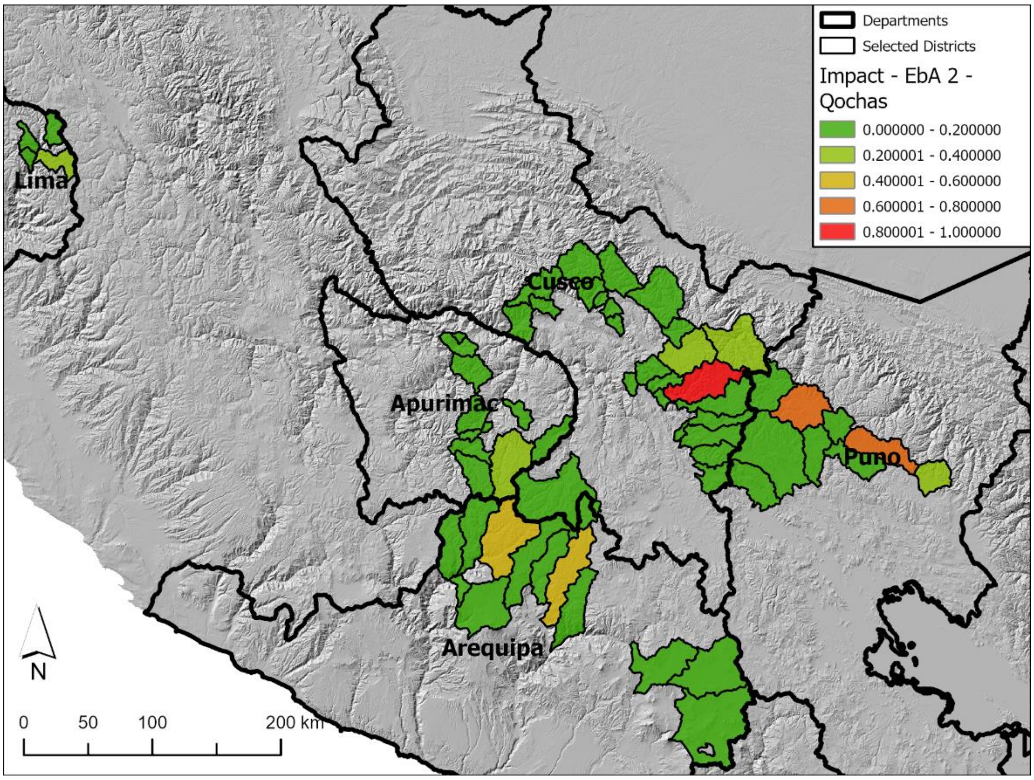

Figure 20. Spatial distribution of the EbA 2 (Qochas) impact for the selected districts in the Puna Region

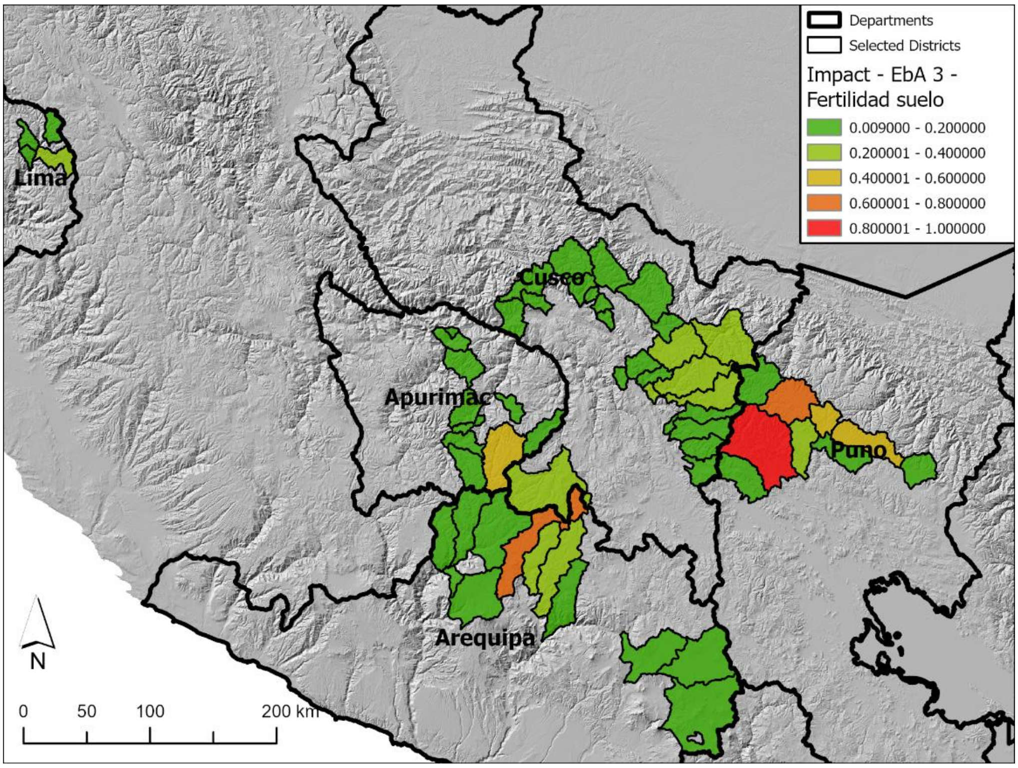

Figure 21. Spatial distribution of the EbA 3 (Fertilidad suelo) impact for the selected districts in the Puna Region

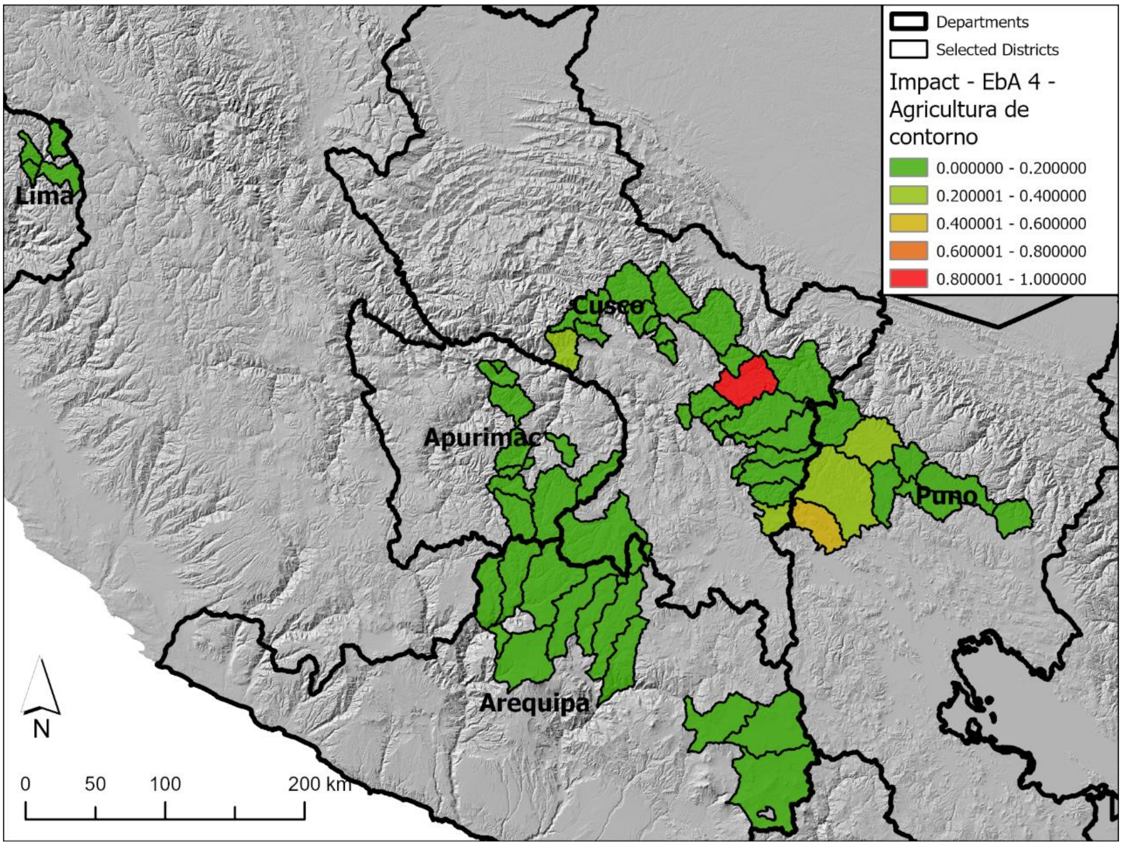

Figure 22. Spatial distribution of the EbA 4 (Agricultura de contorno) impact for the selected districts in the Puna Region

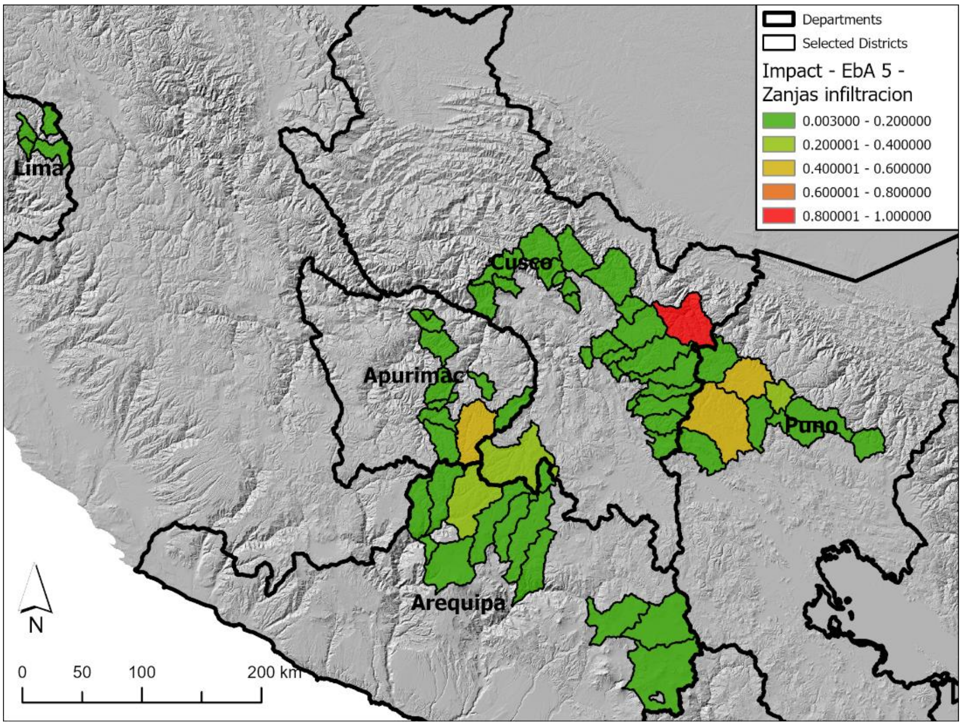

Figure 23. Spatial distribution of the EbA 5 (zanjas infiltracion) impact for the selected districts in the Puna Region

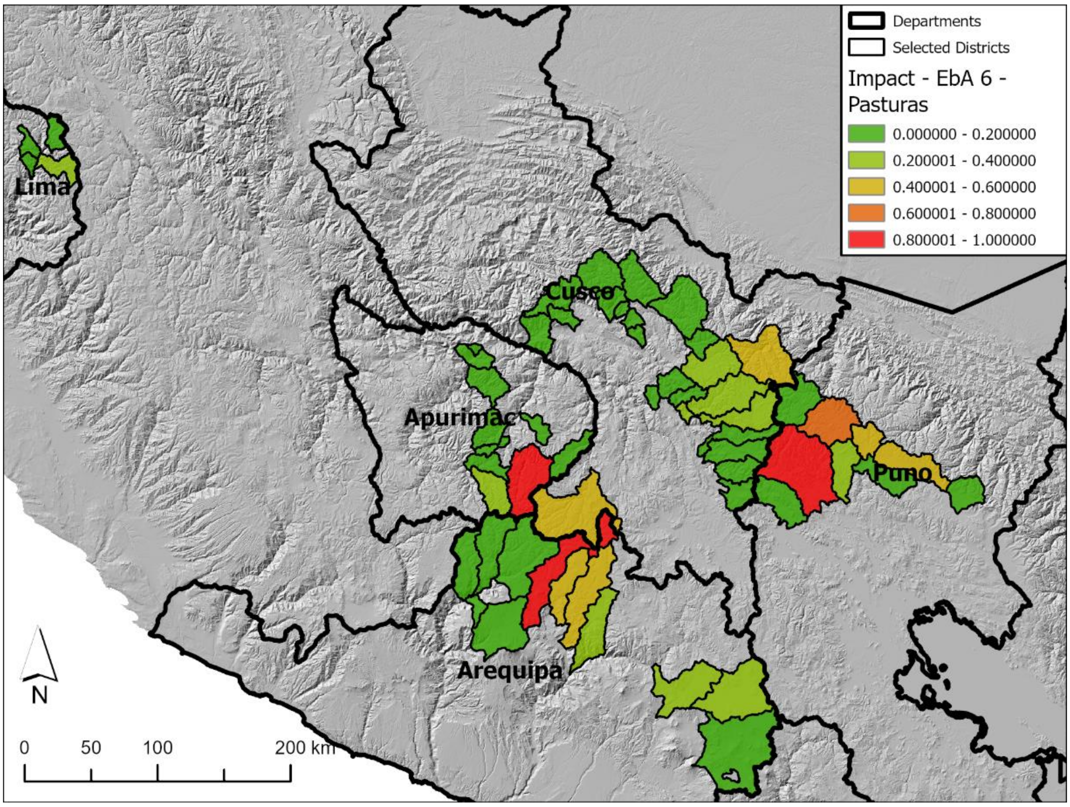

Figure 24. Spatial distribution of the EbA 6 (Pasturas) impact for the selected districts in the Puna Region

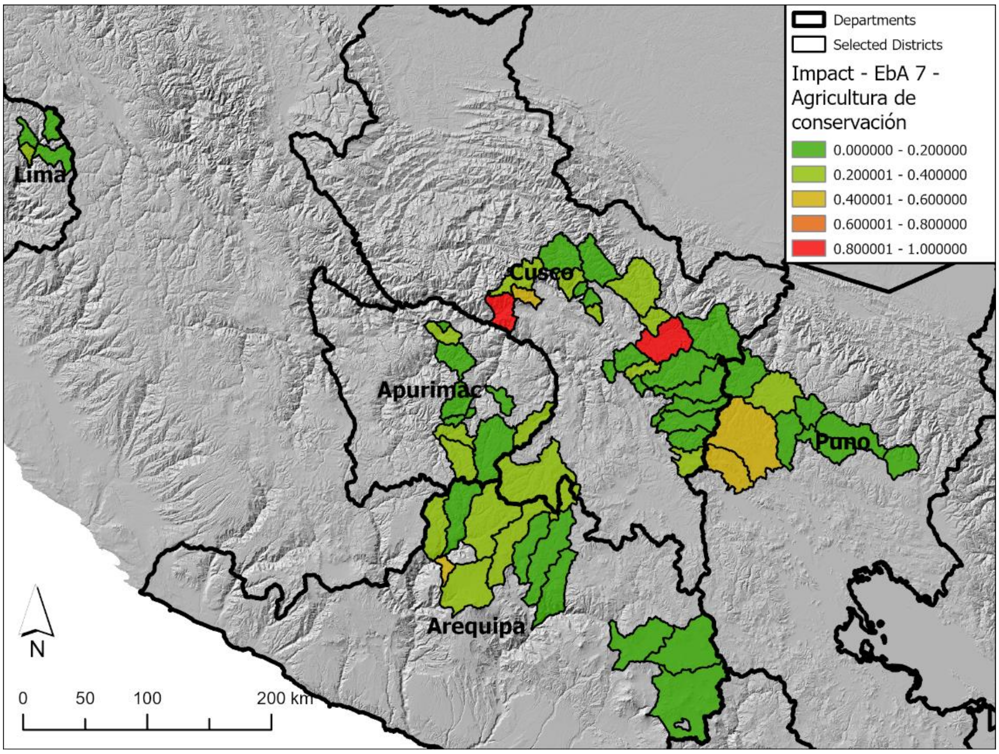

Figure 25. Spatial distribution of the EbA 7 (Agricultura de conservación) impact for the selected districts in the Puna Region

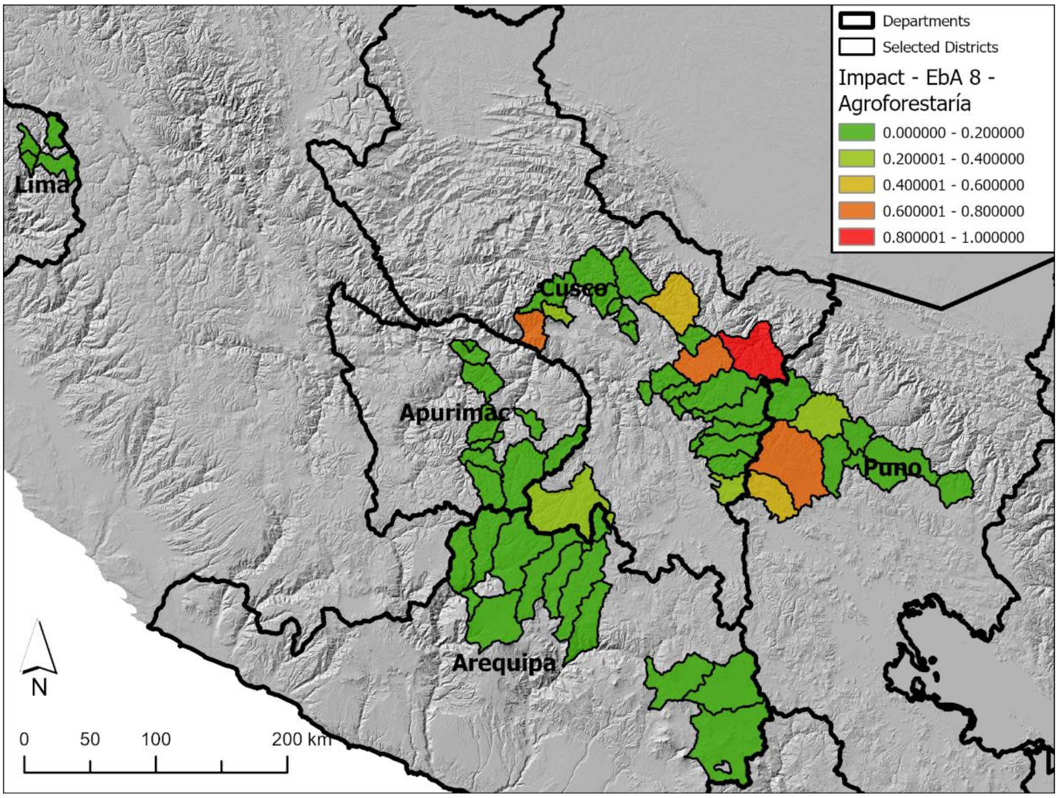

Figure 26. Spatial distribution of the EbA 8 (Agroforestaría) impact for the selected districts in the Puna Region

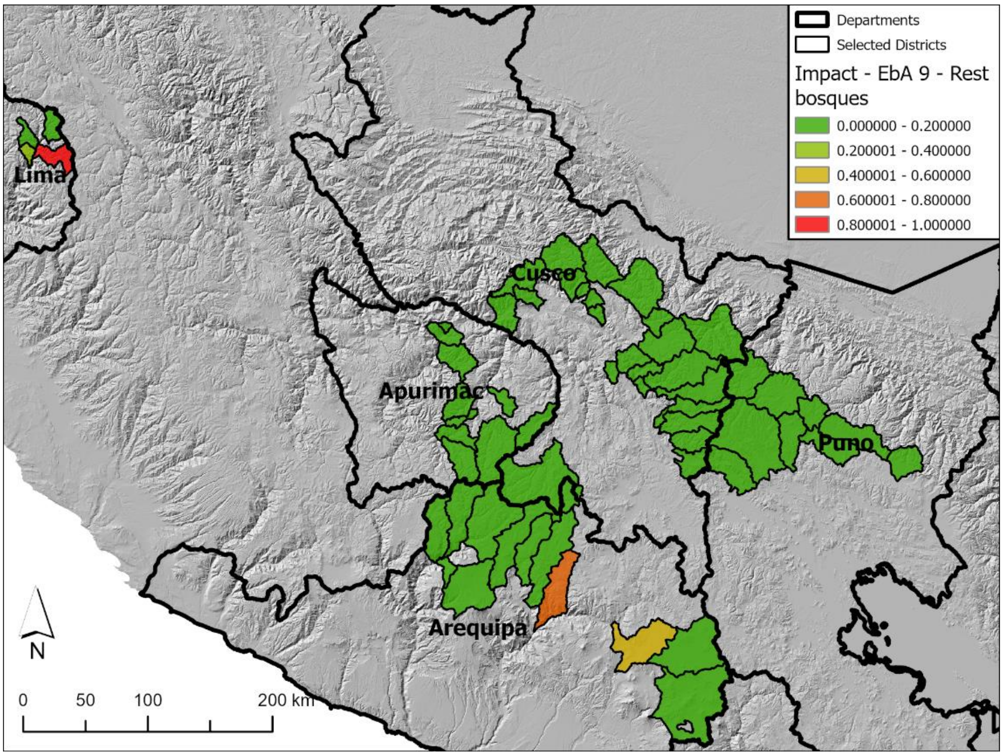

Figure 27. Spatial distribution of the EbA 9 (Rest bosques) impact for the selected districts in the Puna Region

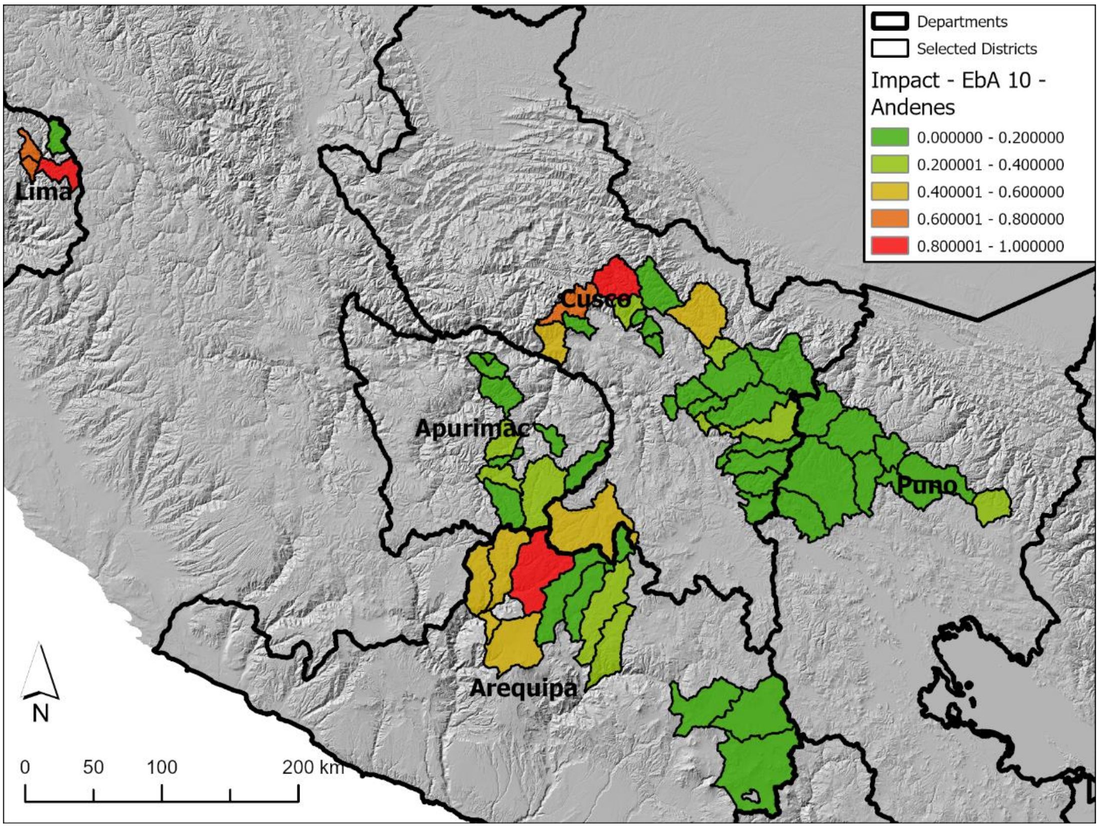

Figure 28. Spatial distribution of the EbA 10 (Andenes) impact for the selected districts in the Puna Region