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Supplement of

Assessing agriculture's vulnerability to drought in European pre-Alpine regions

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S1 Semi-structured interview with each of the experts to identify vulnerability factors

The semi-structured interviews were held online and individually with each expert between the 24th August to 9th September 2021. The interviews followed the below presented questions (see Table S1) with a flexible interactive structure allowing to integrate the established questions with further information on the context and expertise from each participant. Therefore, the discussions were supported by slides documenting answers and explanations.

Table S1. Established questions guiding through the semi-structured interviews.

Identifying and directing the vulnerability factors: Some factors can make the agricultural sector more vulnerable to drought, others can make it less vulnerable.

1. Can you list these factors for Thurgau/Podravska?
2. Can you specify if such factors are making the region less or more vulnerable?
3. Can you explain how/why?
4. Now we show you what other stakeholders answered/ we included so far in our study. Do you agree with these selected factors?
5. Can you specify if such (previously identified) factors are making the region less or more vulnerable?

Importance rating of the factors contributing to the regions' vulnerability:

6. Here are all the factors you selected as increasing vulnerability to drought. How important from low, medium and high are these factors in increasing vulnerability (with "high" means the factor has a high effect making the region more vulnerable)?
7. Here are all the factors you selected as decreasing vulnerability to drought. How important from low, medium and high are these factors in decreasing vulnerability (with "high" means the factor has a high effect making the region less vulnerable)?

Indicators to represent the factors quantitatively:

8. Here are factors which were previously identified. For each factor we identified an indicator and available data to describe how the factor varies temporally and spatially throughout the Thurgau region.
    a. Do you think the indicators well describes/characterise the respective factors?
    b. Is there any other indicator (with available data) we could use to describe the respective factor?

S2 Participatory validation of the mapped factors and vulnerability

The participatory validation was held online with two groups, one consisting of the experts for Podravska and held on the 10th June, 2022 and the other consisting of the experts for Thurgau held on 21st June, 2022. The discussion followed the below presented questions (see Table S2) with a flexible interactive structure allowing to integrate the established questions with further information on the context and expertise from all participants. Therefore, the discussions were supported by slides documenting answers and explanations.

Table S2. Established questions guiding through participatory validation.

Assembling region-specific knowledge about most and least vulnerable subregions:

- According to your perception/knowledge, where do you think agricultural areas are more vulnerable to drought in Thurgau/Podravska?
- According to your perception/knowledge, where do you think agricultural areas are less vulnerable to drought in Thurgau/Podravska?

Validating the single factor maps that received highest importance according to the previous interview (between the 24th August to 9th September 2021**):**

Podravska:

- Do the maps present reasonable differences in soil texture, irrigated land, tourist farms and access to local food market across Podravska? Do the maps make sense to you?
    - Soil texture more coarse (higher vulnerability) in the center of the region between Maribor and Ptuj
    - Permanently irrigated land mainly located in the center and along the river (lower vulnerability)
    - Is the region in the East more touristic?
    - Is the access to local food market lower in the North and South?

Thurgau:

- Do the maps present reasonable differences in distance to large water bodies, irrigated land, humus content, soil texture, and water holding capacity across Thurgau? Do the maps make sense to you?
    - Distance to large water bodies large between Lake Constance and the rivers Thur and Murg, as well as in the South (higher vulnerability)?
    - Is the permanently irrigated land homogenous distributed rather homogeneous across Thurgau with slightly less irrigation in the South, at the coastline and along the river Thur?
    - Is the humus content high along the river Thur, and apart from that very low?
    - Are the clay-rich soil patches in areas in the Northwest, along the river Thur and between the cities Frauenfeld and Sirnach?
    - Is the water holding capacity low in Northern Thurgau?

Validating the vulnerability aggregated with the equal and expert weighting method:

- To what extent do you think that the darker red areas have a higher vulnerability to droughts compared to lighter-coloured areas?
- Is there any subregion which is depicted as more or less vulnerable compared to your perception/knowledge?
- Have darker areas experienced greater impacts/damage during past drought events compared to lighter-coloured areas?
- Does the expert weighting map make more sense to you compared to the equal weighting? Why?

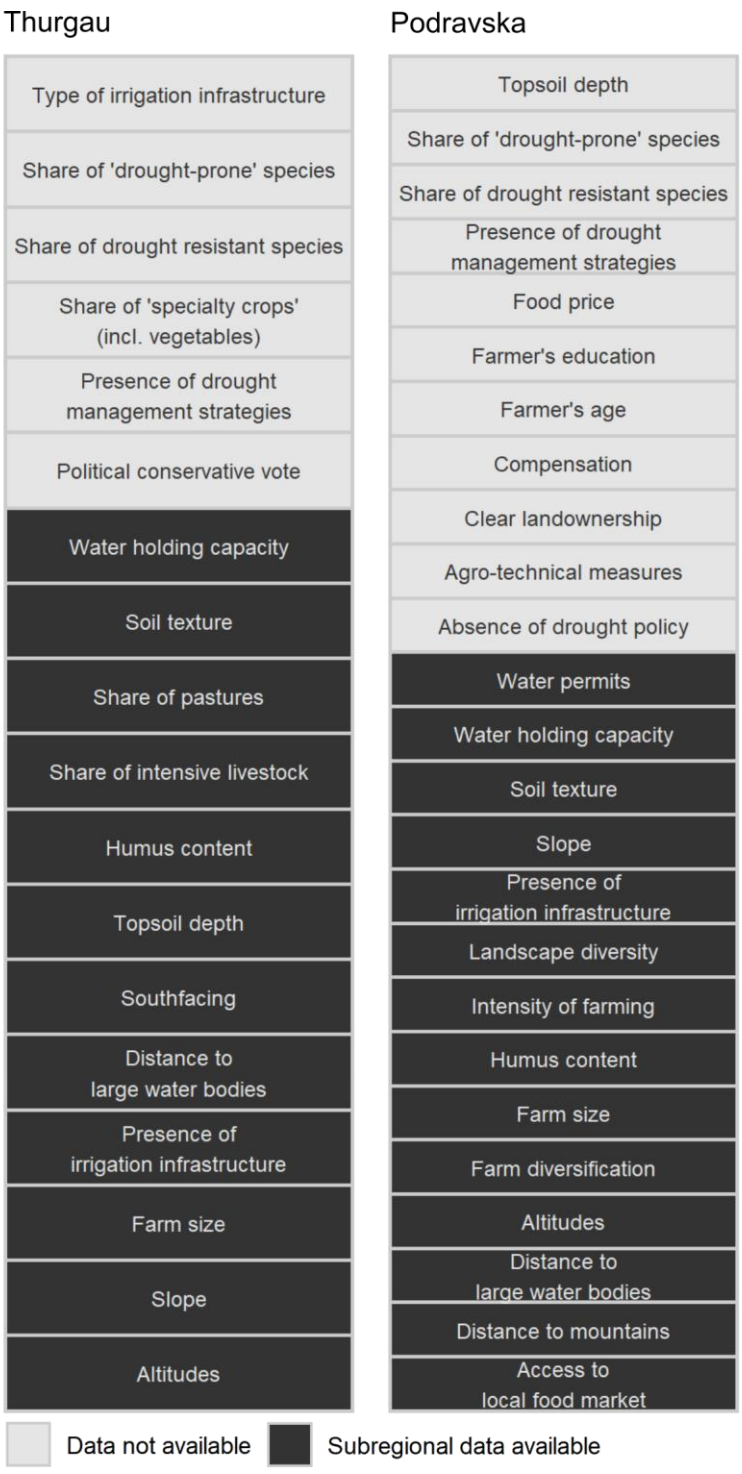

Figure S1. Data availability of vulnerability factors identified by the local experts of Thurgau and Podravska.

Table S3. Thurgau's vulnerability factors with subregional data availability to compute indicators describing the factors quantitatively. For the spatial distribution of the factors see Fig. S2.

Factor	**Indicator calculation**
Altitudes	Digital elevation model from 2016 (EU-DEM, 2022) used to define altitudes in masl with a resolution of 100m*100m.
Slope	Digital elevation model from 2016 (EU-DEM, 2022) used to calculate slope in rad with a resolution of 100m*100m.
Southfacing area	Shapefile from 2005 developed to indicate soil features across Thurgau (Amt für Geoinformationen Thurgau, 2022) is used. The feature "Exposure" is used to select hillsides exposed to the South. Then, the southfacing and non-southfacing hillsides are classified to 1 and 0.
Distance to large water bodies	Raster showing the distance calculated at each location to the nearest lakes, water reservoirs (national shapefile from 2020 by FOEN) and rivers (European shapefile from 2020 by EU-Hydro). Rivers were filtered to Strahler-Index ≥ 3.
Presence of irrigation infrastructure	Landcover data indicating "permanently irrigated land" from 2018 across Europe with a resolution of 250m*250m is selected (CLC, 2022).
Farm size	The indicator "number of farms > 30 ha" specified for LAU2 from 2019 regions is used (SFSO, 2022).
Share of intensive livestock	The indicator "Livestock units (LU)" specified for LAU1 from 2020 regions is used (SFSO, 2022).
Share of pastures	The indicator "Number of farms specialized for pasture farming" from 2020 specified for LAU1 regions is used (SFSO, 2022).
Soil texture	Shapefile from 2005 developed to indicate soil features across Thurgau (Amt für Geoinformationen Thurgau, 2022) is used. The feature "dominant soil texture" is available in 5 classes and used as follows: clay → 1 clar rich silt → 2 sandy clay → 2 clayey loam → 2 clar rich sand→ 3
Topsoil depth	Shapefile from 2005 developed to indicate soil features across Thurgau (Amt für Geoinformationen Thurgau, 2022) is used. The feature "dominant topsoil depth" is available in 5 classes and used as follows: very profound→ 1 profound → 2 moderate profound → 3 quite shallow → 4 shallow and very shallow → 5
Humus content	Shapefile from 2006 to indicate soil features across Europe (ESDAC, 2022) is used. The indicator "topsoil organic carbon content [%]" is available in 4 classes and used as follows: high [> 6 %] → 1 medium [2.1 % - 6 %] → 2 low [1.1 % - 2 %] → 3 very low [< 2 %] → 4
Water holding capacity	Shapefile from 2006 to indicate soil features across Europe (ESDAC, 2022) is used. The indicator "topsoil available water capacity [mm]" is available in 4 classes and used as follows: high [> 190 mm] → 1 medium [140 mm - 189 mm] → 2 low [100 mm - 139 mm] → 3 very low [< 99 mm] → 4

Table S4. Podravska's vulnerability factors with subregional data availability to compute indicators describing the factors quantitatively. For the spatial distribution of the factors see Fig. S3.

Factor	**Indicator calculation**
Altitudes	Digital elevation model from 2017 used to define altitudes in masl with a resolution of 100m*100m (INSPIRE, 2022).
Slope	Digital elevation model from 2017 used to calculate slope in rad with a resolution of 100m*100m (INSPIRE, 2022).
Distance to large water bodies	Raster showing the distance calculated at each location to the nearest lakes, water reservoirs (national shapefile from 2017 by INSPIRE) and rivers (European shapefile from 2020 by EU-Hydro). Rivers were filtered to Strahler-Index ≥ 3.
Distance to mountains	Raster showing the distance calculated at each location to the nearest mountain (European mountain areas as defined by the European Environment Agency)
Presence of irrigation infrastructure	Landcover data indicating "permanently irrigated land" from 2018 across Europe with a resolution of 250m*250m is selected (CLC, 2022).
Intensity of farming	Shapefile developed combining information on the agricultural parcels with declared crop for 2020 (INSPIRE, 2022) and the statistical values of annual average yield for 2010 and showing the average agricultural production per each agricultural parcel (SURS, 2022).
Farm size	Shapefile created with the 2010 data of average utilised agricultural area per agricultural holding [ha] from SURS (2022) for each LAU 2 region.
Landscape diversity	Raster showing the Shannon eveness index (SEI) with information on area composition and richness ranging from 0 to 1. SEI is calculated by considering 9 Land Cover classes (CLC, 2018) of numeric matrices, using a moving window algorithm of 5 pixels side and dividing this result by its maximum.
Water permits	Shapefile data on the water permits points for 2012 with information on the type of direct water uses (INSPIRE, 2022).
Access to local food market	Shapefile created with the 2010 data on the percentage of agricultural holdings with main destination for sale per each LAU2 region from SURS (2022).
Farm diversification	Shapefile created with the 2009/2010 data on the average number of permanent beds per agricultural holding [no] per each LAU2 region from SURS (2022).
Soil texture	Shapefile from 2006 to indicate soil features across Europe (ESDAC, 2022) is used. The indicator "Subsoil textural class" is available in 5 classes and used as follows: coarse → 5 medium → 4 medium fine → 3 fine → 2 very fine → 1
Humus content	Shapefile from 2006 to indicate soil features across Europe (ESDAC, 2022) is used. The indicator "topsoil organic carbon content [%]" is available in 4 classes and used as follows: high [> 6 %] → 1 medium [2.1 % - 6 %] → 2 low [1.1 % - 2 %] → 3 very low [< 2 %] → 4
Water holding capacity	Shapefile from 2006 to indicate soil features across Europe (ESDAC, 2022) is used. The indicator "topsoil available water capacity [mm]" is available in 4 classes and used as follows: high [> 190 mm] → 1 medium [140 mm - 189 mm] → 2 low [100 mm - 139 mm] → 3 very low [< 99 mm] → 4

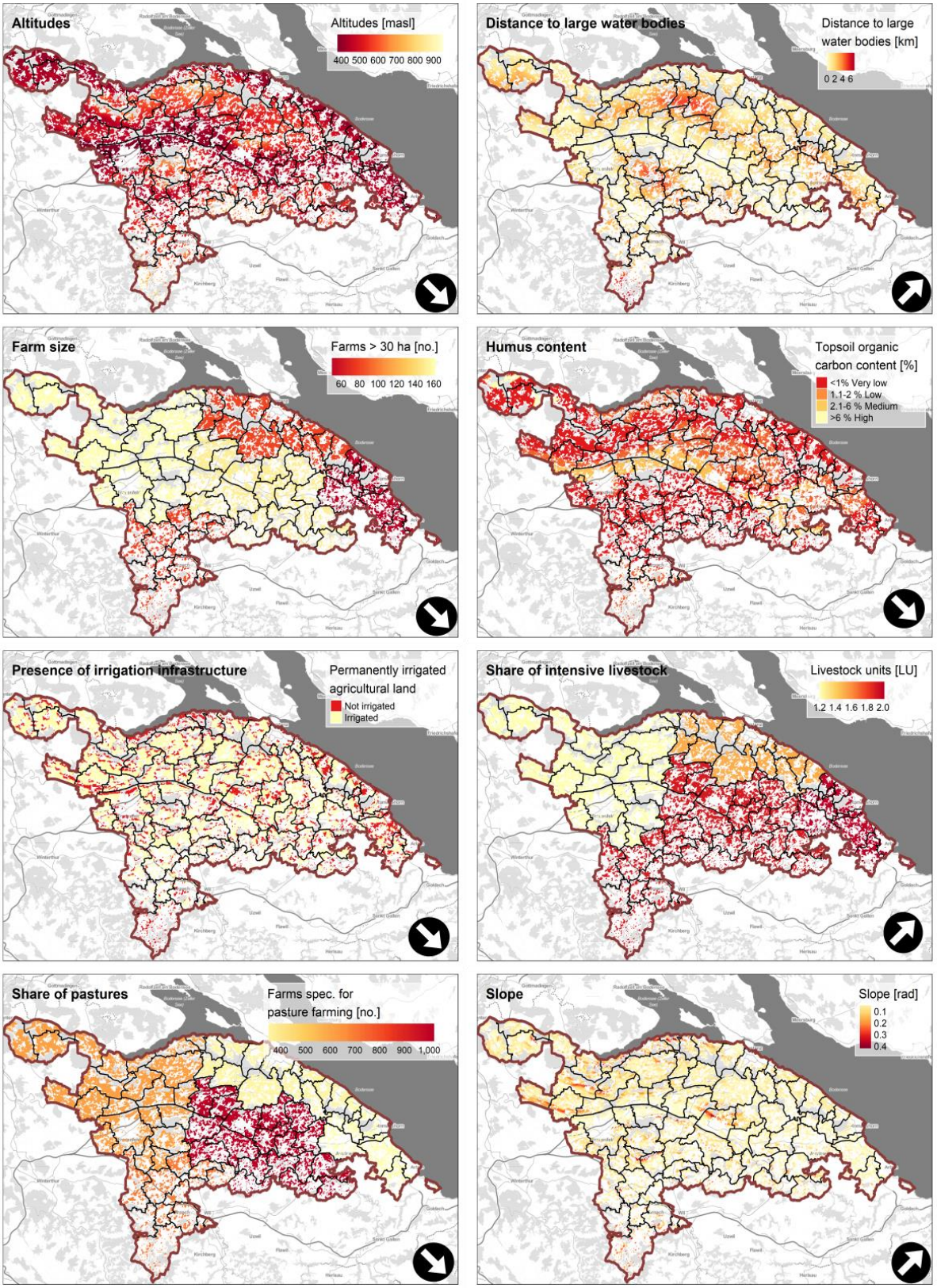

Figure S2. Thurgau's factors (bold title) and the selected indicators used for the calculation of the vulnerability maps (see Table 1, Fig. 5) and masked with agricultural used land. The factor's increasing or decreasing effect on the vulnerability is indicated by the arrow in the map (bottom right) and by the colour choice (the darker the colour, the higher the vulnerability).

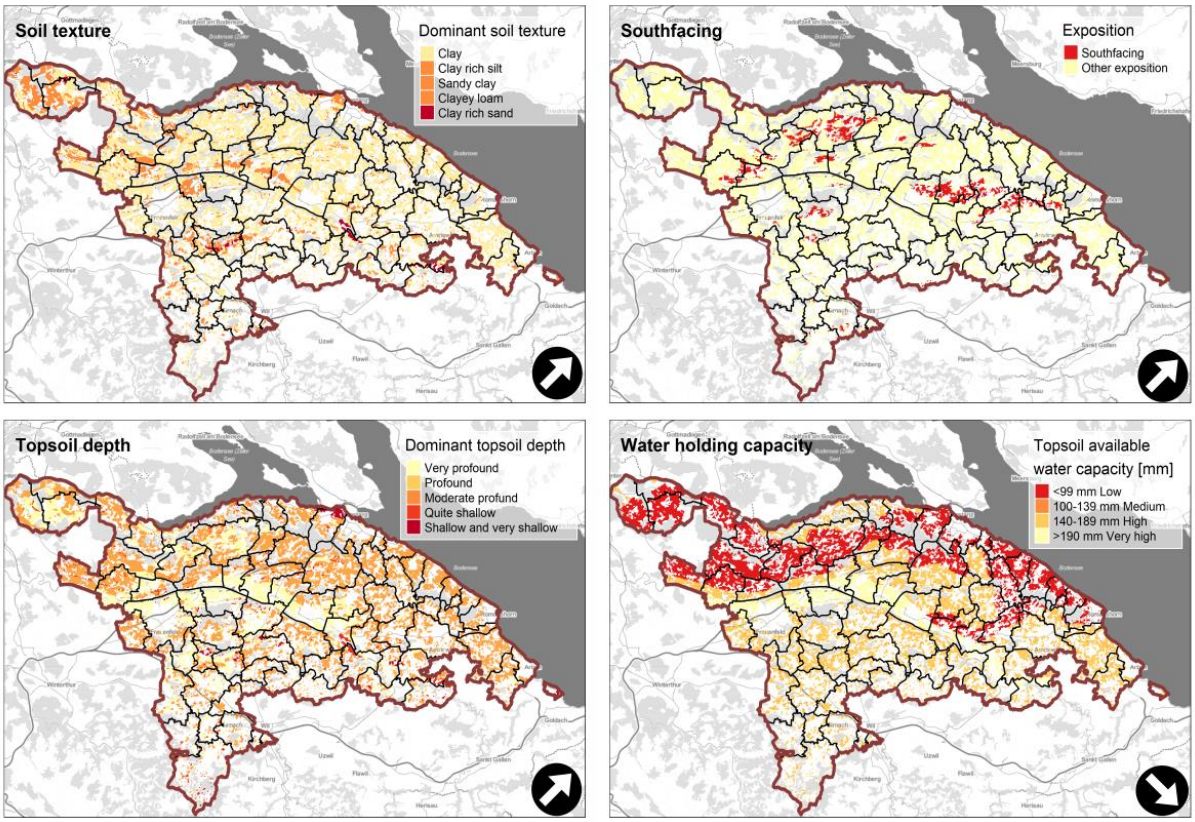

Figure S2. Continued.

Table S5. Thurgau LAU2 regions name, the final vulnerability values according to the equal and expert weighting scheme and their difference.

LAU2 code	LAU2 name	Equal weighting	Expert weighting	Diff(Expert-Equal)
816	Homburg	0.297	0.236	0.061
846	Raperswilen	0.348	0.287	0.060
811	Herdern	0.309	0.250	0.059
536	Basadingen-Schlattingen	0.269	0.214	0.054
701	Wäldi	0.296	0.247	0.049
821	Hüttwilen	0.275	0.227	0.047
606	Stettfurt	0.250	0.207	0.044
546	Schlatt (TG)	0.231	0.188	0.043
601	Neunforn	0.260	0.222	0.038
616	Uesslingen-Buch	0.280	0.242	0.038
806	Eschenz	0.209	0.172	0.037
841	Pfyn	0.227	0.191	0.036
871	Wagenhausen	0.209	0.173	0.036
571	Gachnang	0.208	0.173	0.034
611	Thundorf	0.156	0.122	0.033
591	Matzingen	0.181	0.150	0.031
681	Langrickenbach	0.216	0.187	0.029
666	Kemmental	0.262	0.233	0.029
621	Warth-Weiningen	0.209	0.184	0.025
683	Lengwil	0.232	0.208	0.024
831	Müllheom	0.160	0.141	0.019
656	Güttingen	0.207	0.188	0.019
741	Lommis	0.270	0.251	0.019
696	Tägerwilen	0.214	0.195	0.019
561	Felben-Wellhausen	0.160	0.142	0.018
545	Diessenhofen	0.164	0.147	0.017
711	Affeltrangen	0.199	0.186	0.013
566	Frauenfeld	0.108	0.097	0.011
646	Ermatingen	0.162	0.151	0.011
446	Sommeri	0.202	0.192	0.010
641	Altnau	0.256	0.247	0.009
691	Münsterlingen	0.237	0.228	0.009
643	Bottighofen	0.133	0.124	0.009
590	Hüütlingen	0.092	0.083	0.009
724	Eschlikon	0.134	0.128	0.006
851	Salenstein	0.131	0.126	0.006
776	Tobel-Tägerschen	0.145	0.139	0.005
756	Schönholzerswilen	0.145	0.140	0.005
723	Braunau	0.113	0.109	0.004
791	Wuppenau	0.072	0.068	0.004
826	Mammern	0.132	0.129	0.004
476	Erlen	0.215	0.212	0.003
671	Kreuzlingen	0.077	0.075	0.003
551	Aadorf	0.137	0.135	0.002
716	Bettwiesen	0.063	0.061	0.002
864	Steckborn	0.091	0.089	0.002
911	Bürglen	0.245	0.244	0.001
921	Bussnang	0.208	0.207	0.001
781	Wängi	0.135	0.133	0.001

Table S5. Continued.

LAU2 code	LAU2 name	Equal weighting	Expert weighting	Diff(Expert-Equal)
746	Münchwilen (TG)	0.111	0.110	0.001
786	Wilen (TG)	0.062	0.062	0.000
951	Wigoltingen	0.256	0.256	0.000
901	Birwinken	0.218	0.219	0.000
721	Bichelsee-Balterswil	0.050	0.050	-0.001
751	Rickenbach (TG)	0.088	0.089	-0.001
471	Bischofszell	0.113	0.115	-0.002
436	Romanshorn	0.111	0.113	-0.003
461	Amriswil	0.145	0.148	-0.003
881	Amlikon-Bissegg	0.172	0.175	-0.003
506	Sulgen	0.197	0.201	-0.004
431	Roggwil (TG)	0.162	0.166	-0.004
761	Sirnach	0.081	0.086	-0.004
416	Hefenhofen	0.217	0.222	-0.005
501	Kradolf-Schönenberg	0.139	0.144	-0.005
726	Fischingen	0.045	0.050	-0.006
486	Hauptwil-Gottshaus	0.102	0.108	-0.006
511	Zihlschlacht-Sitterdorf	0.161	0.168	-0.007
421	Horn	0.083	0.091	-0.007
426	Kesswil	0.244	0.251	-0.007
941	Märstetten	0.209	0.217	-0.007
401	Arbon	0.075	0.084	-0.009
891	Berg (TG)	0.264	0.273	-0.009
495	Hohentannen	0.121	0.131	-0.010
801	Berlingen	0.063	0.074	-0.011
451	Uttwil	0.145	0.160	-0.015
651	Gottlieben	0.120	0.136	-0.016
411	Egnach	0.191	0.208	-0.017
441	Salmsach	0.217	0.235	-0.018
406	Dozwil	0.244	0.263	-0.019
946	Weinfelden	0.161	0.181	-0.020

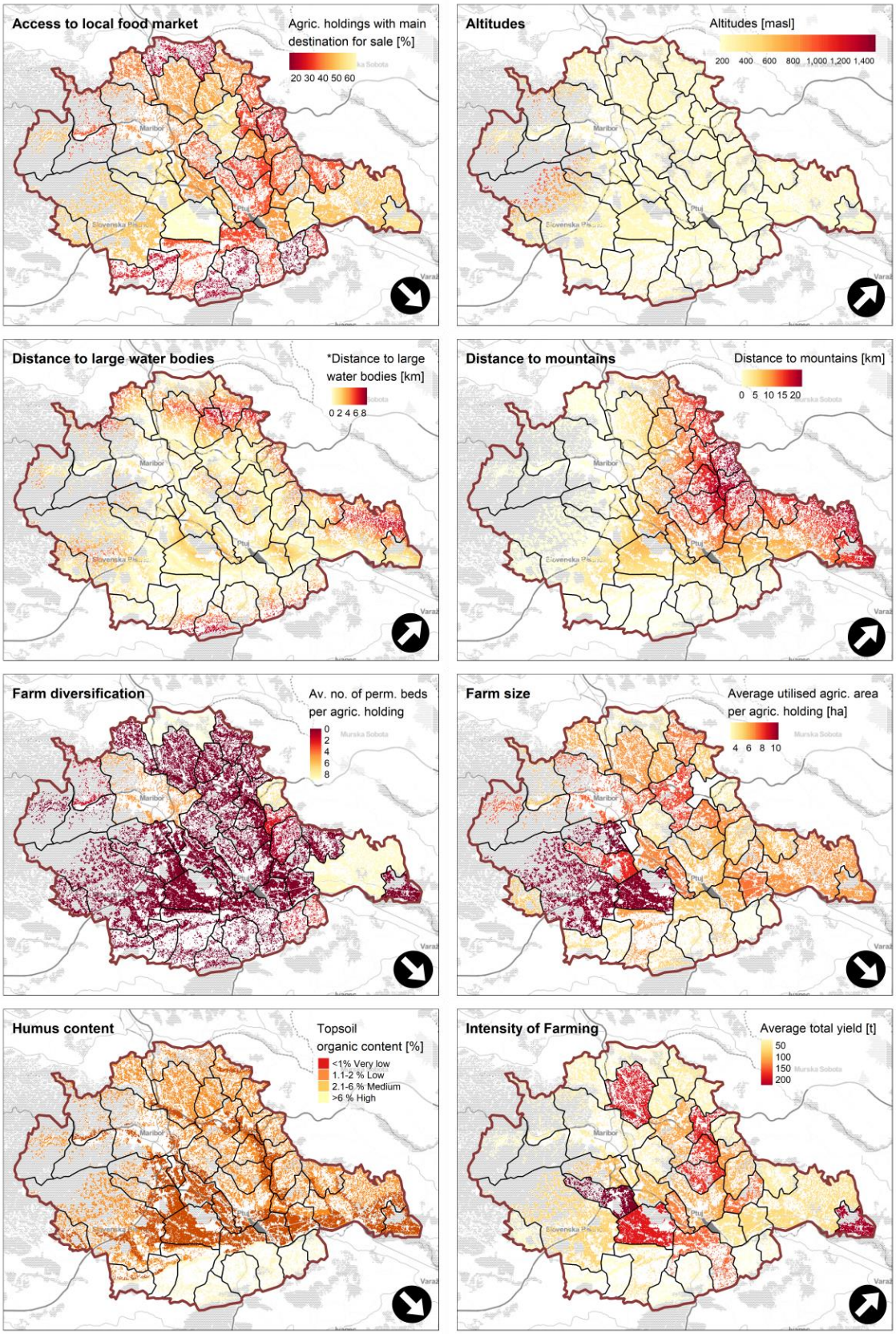

Figure S3. Podravska's factors (bold title) and the selected indicators used for the calculation of the vulnerability maps (see Table1, Fig. 5) and masked with agricultural used land. The factor's increasing or decreasing effect on the vulnerability is indicated by the arrow in the map (bottom right) and by the colour choice (the darker the colour, the higher the vulnerability).

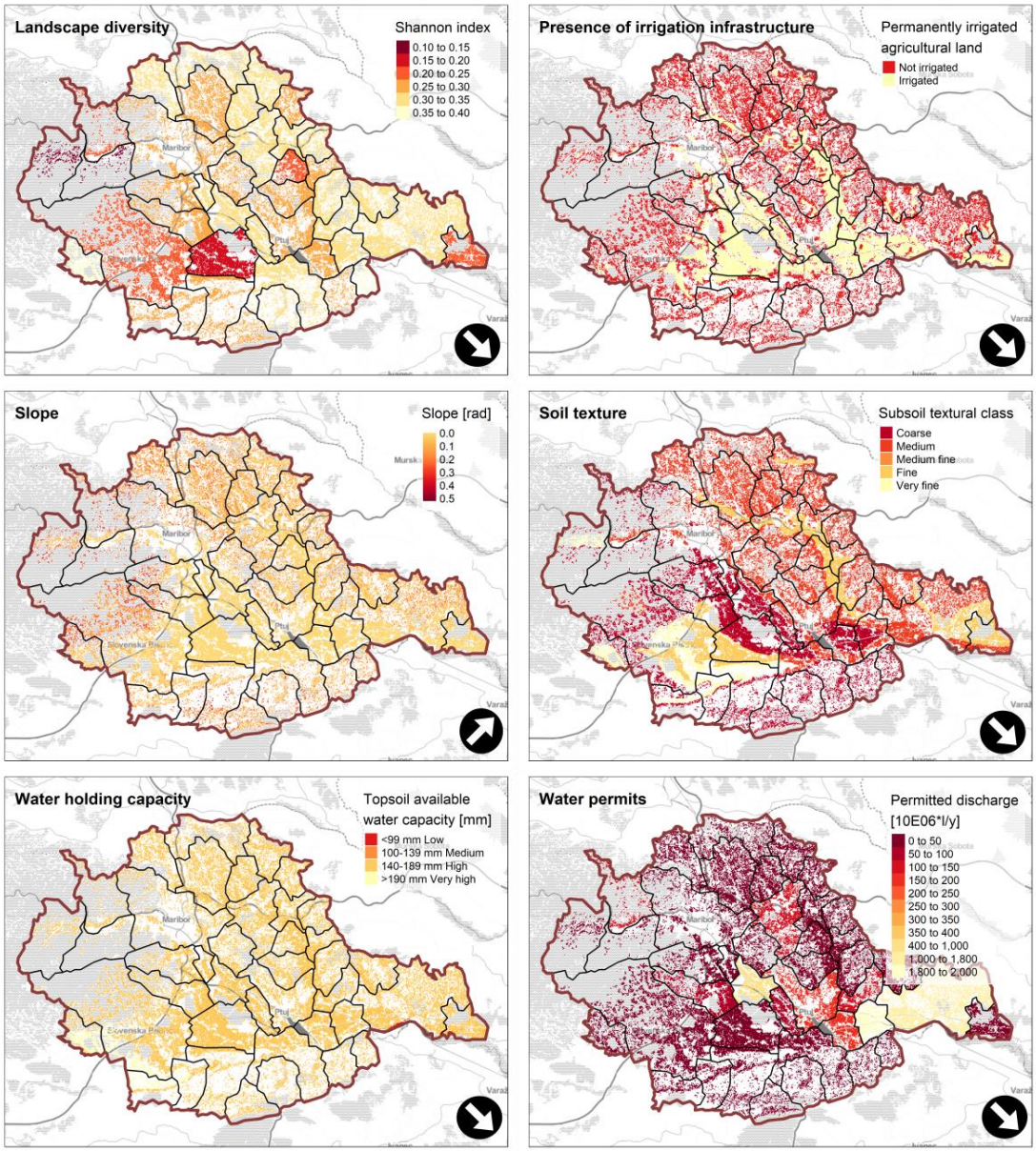

Figure S3. Continued.

Table S6. Podravska LAU2 regions name, the final vulnerability values according to the equal and expert weighting scheme and their difference.

LAU2 code	LAU2 name	Equal weighting	Expert weighting	Diff(Expert-Equal)
35	Sveti Jurij v Slov. goricah	0.283	0.349	0.066
7	Gorišnica	0.172	0.228	0.056
12	Kungota	0.174	0.226	0.052
1	Benedikt	0.269	0.321	0.052
31	Starše	0.189	0.239	0.05
19	Miklavž na Dravskem Polju	0.156	0.206	0.05
8	Hajdina	0.233	0.283	0.05
36	Sveti Tomaž	0.242	0.291	0.049
32	Sveta Ana	0.238	0.287	0.049
18	Markovci	0.214	0.261	0.047
20	Oplotnica	0.137	0.183	0.046
22	Pesnica	0.251	0.294	0.043
39	Videm	0.191	0.233	0.042
41	Žetale	0.149	0.188	0.039
33	Sveta Trojica v Slov. goricah	0.241	0.279	0.038
9	Hoče – Slivnica	0.123	0.161	0.038
6	Duplek	0.166	0.203	0.037
24	Poljčane	0.099	0.135	0.036
13	Lenart	0.2	0.236	0.036
40	Zavrč	0.136	0.172	0.036
10	Juršinci	0.221	0.254	0.033
25	Ptuj	0.185	0.218	0.033
3	Cirkulane	0.129	0.162	0.033
16	Makole	0.112	0.145	0.033
23	Podlehnik	0.109	0.142	0.033
5	Dornava	0.224	0.255	0.031
26	Rače–Fram	0.197	0.228	0.031
4	Destrnik	0.27	0.301	0.031
15	Majšperk	0.128	0.157	0.029
29	Slovenska Bistrica	0.123	0.15	0.027
21	Ormož	0.15	0.174	0.024
37	Šentilj	0.137	0.161	0.024
28	Selnica ob Dravi	0.075	0.095	0.02
2	Cerkvenjak	0.199	0.219	0.02
38	Trnovska vas	0.293	0.312	0.019
17	Maribor	0.079	0.097	0.018
34	Sveti Andraž v Slovenskih goricah	0.263	0.28	0.017
14	Lovrenc na Pohorju	0.041	0.049	0.008
27	Ruše	0.032	0.04	0.008
11	Kidričevo	0.223	0.229	0.006
30	Središče ob Dravi	0.232	0.233	0.001

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