Supplementary Material

Table S1: Mathematical derivation of the formula for the 'disease-index'.

Steps of mathematical derivation

1)	**Problem:** We want to calculate an index which indicates the probability that a particular apiary in the study area was affected at least once (by AFB or EFB) during the last 26 years (1991-2016). Given are the number of disease outbreaks (in the last 26 years) as well as the number of apiaries (end of 2016).
2)	**Annotations:** n: number of apiaries k: number of disease outbreaks in the last 26 years (312 months)
3)	**Mathematical derivation of the formula:** The model assumption is that all data are evenly distributed. Furthermore, a certain apiary should have exactly once a month the opportunity to have a disease outbreak. It either stays healthy for the whole month or shows symptoms, which is reported as one disease outbreak. Due to the evenly distributed data required in the model, there are $\frac{k}{312}$ disease outbreaks per month. The probability that one out of n apiaries will show a disease outbreak in a given month is $\frac{1}{n} \times \frac{k}{312} = \frac{k}{312n}$. The probability q that the same apiary stays healthy in a given month is $q = 1 - \frac{k}{312n}$. The probability that it remains healthy for 26 years (312 month) is thus $q^{312} = (1 - \frac{k}{312n})^{312}$. The probability p that it has a disease outbreak at least once during the entire period is: $p = 1 - q^{312} = 1 - (1 - \frac{k}{312n})^{312}$. Multiplied by the factor 100, the probability ('disease-index') is given in %.
4)	**Example:** Probability that a particular apiary in the canton of Bern was affected at least once (by EFB) during the last 26 years (1991-2016) → 'disease-index' for EFB in the canton of Bern (1991-2016) *n: number of apiaries* *5327 (Table 1)* *k: number of EFB outbreaks in the last 26 years (312 month)* *3104 (Table 1)* **'disease-index'** = $(1 - \left(1 - \frac{k}{312n}\right)^{312}) \times 100 = \left(1 - \left(1 - \frac{3104}{312 \times 5327}\right)^{312}\right) \times 100 = \mathbf{44.2}\ \%$

Table S2: Spatial data on district level for number of active apiaries and densities; and bee brood diseases announcements (AFB and EFB) in the contiguous study area (without exclaves) Bern (BE), Solothurn (SO) and Aargau (AG) (1991-2016).

		Active apiaries 2016	'Density-index' [km^{-2}]	EFB 1991-2016	EFB 'disease-index'	AFB 1991-2016	AFB 'disease-index'
Berner Jura	**BE**	303	0.56	14	4.5%	7	2.3%
Bern-Mittelland	**BE**	1,577	1.67	1,057	48.9%	108	6.6%
Biel/Bienne	**BE**	149	1.55	120	55.4%	23	14.3%
Emmental	**BE**	1,142	1.65	840	52.1%	20	1.7%
Frutigen-Niedersimmental	**BE**	292	0.38	78	23.5%	20	6.6%
Interlaken-Oberhasli	**BE**	301	0.25	119	32.7%	19	6.1%
Oberaargau	**BE**	534	1.61	307	43.8%	9	1.7%
Obersimmental-Saanen	**BE**	188	0.33	28	13.8%	11	5.7%
Seeland	**BE**	355	1.06	129	30.5%	18	4.9%
Thun	**BE**	479	1.49	412	57.7%	15	3.1%
Balsthal-Thal	**SO**	84	0.60	41	38.6%	0	0.0%
Bucheggberg	**SO**	79	1.26	50	46.9%	3	3.7%
Gäu (and Balsthal-Gäu)	**SO**	58	0.94	40	49.9%	0	0.0%
Gösgen	**SO**	80	1.17	18	20.2%	2	2.5%
Lebern	**SO**	136	1.16	138	63.8%	22	14.9%
Olten	**SO**	72	0.89	30	34.1%	0	0.0%
Solothurn	**SO**	13	2.07	19	76.9%	3	20.6%
Wasseramt	**SO**	80	1.05	64	55.1%	6	7.2%
Aarau	**AG**	127	1.22	18	13.2%	5	3.9%
Baden	**AG**	147	0.96	4	2.7%	6	4.0%
Bremgarten	**AG**	103	0.88	4	3.8%	13	11.9%
Brugg	**AG**	148	1.02	1	0.7%	15	9.6%
Kulm	**AG**	137	1.35	78	43.4%	3	2.2%
Laufenburg	**AG**	187	1.19	10	5.2%	10	5.2%
Lenzburg	**AG**	113	1.10	34	26.0%	6	5.2%
Muri	**AG**	140	1.01	7	4.9%	13	8.9%
Rheinfelden	**AG**	90	0.81	6	6.4%	3	3.3%
Zofingen	**AG**	204	1.44	62	26.2%	4	1.9%
Zurzach	**AG**	105	0.81	3	2.8%	5	4.7%

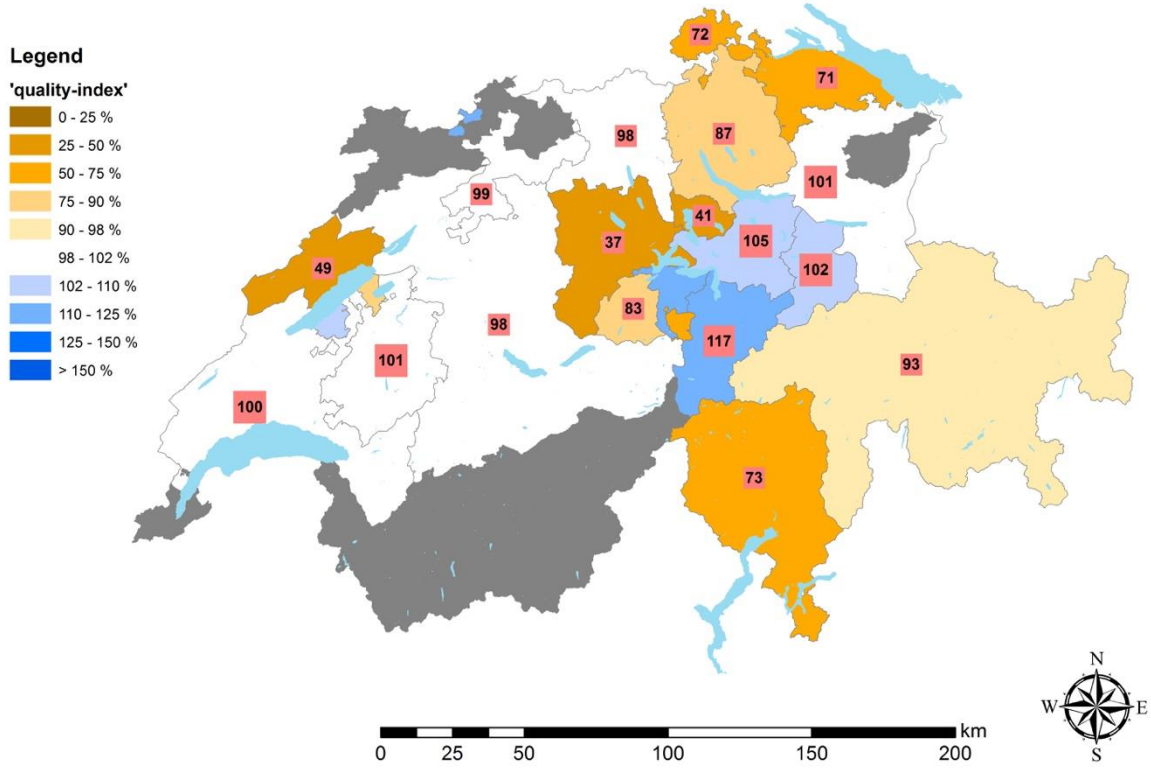

Figure S1: 'Quality-index' on cantonal level. The 'quality-index' gives the proportion of the number of apiaries of the FOAG data set, relative to the number of apiaries of the cantonal data set. Thus, a 'quality-index' of 100% means that there is the same number of apiaries in both data sets. A 'quality-index' > 100% indicates more FOAG-apiaries; < 100% indicates more apiaries in the cantonal data set. Cantons where only one data set was available are indicated in grey (no data to compare).

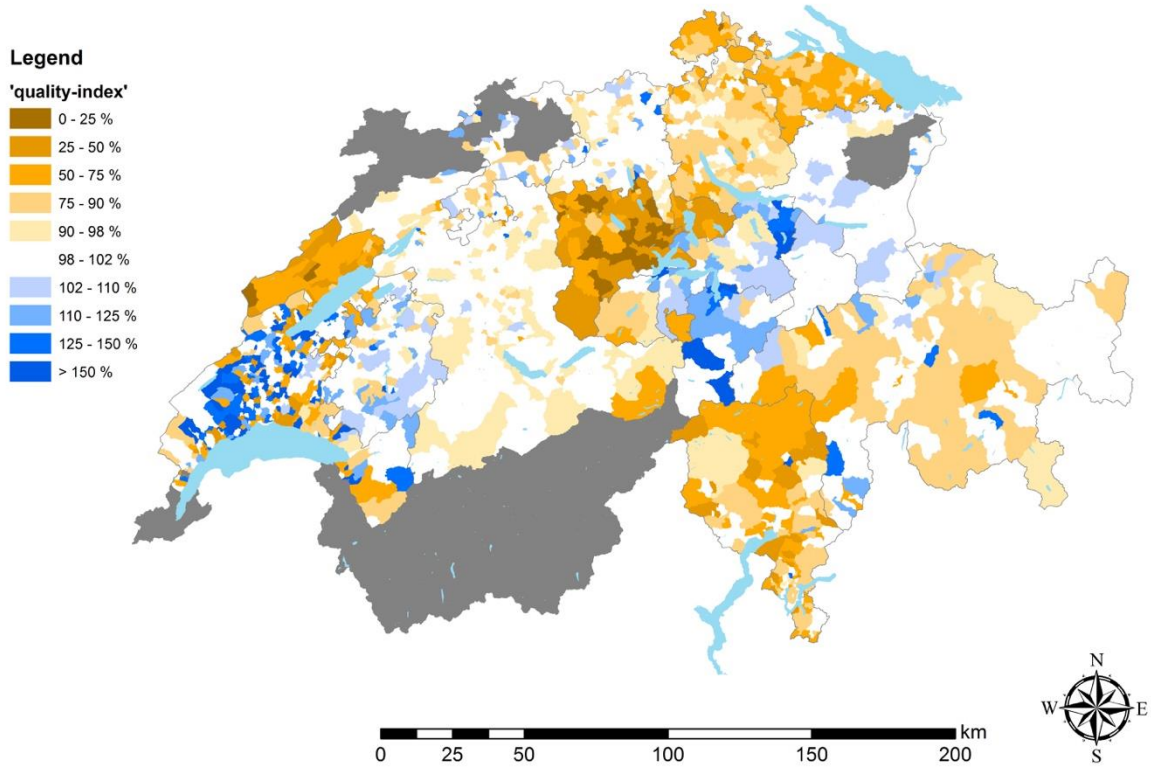

Figure S2: 'Quality-index' on municipal level. The 'quality-index' gives the proportion of the number of apiaries of the FOAG data set, relative to the number of apiaries of the cantonal data set. Thus, a 'quality-index' of 100% means that there is the same number of apiaries in both data sets. A 'quality-index' > 100% indicates more FOAG-apiaries; < 100% indicates more apiaries in the cantonal data set. Municipalities of cantons where only one data set was available are indicated in grey (no data to compare)**.**

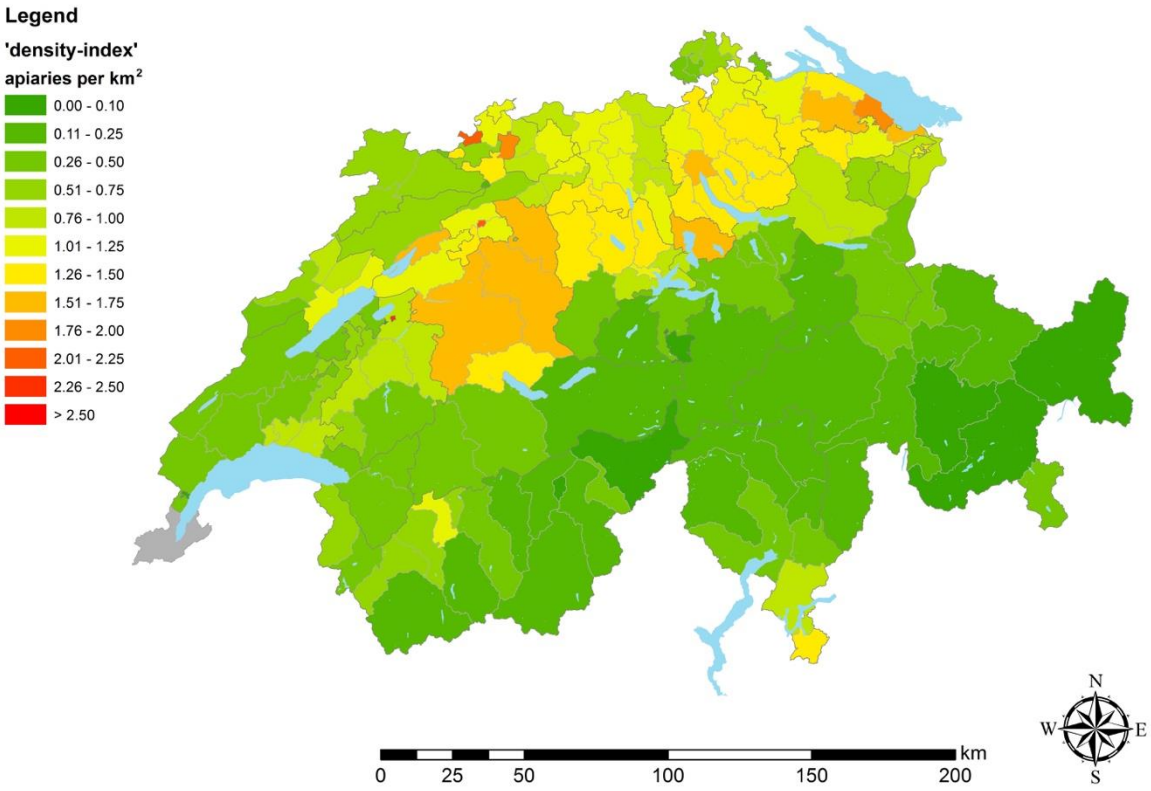

Figure S3: 'Density-index' on district level (2016). Low data quality lead to exclusion of Geneva (indicated in grey).

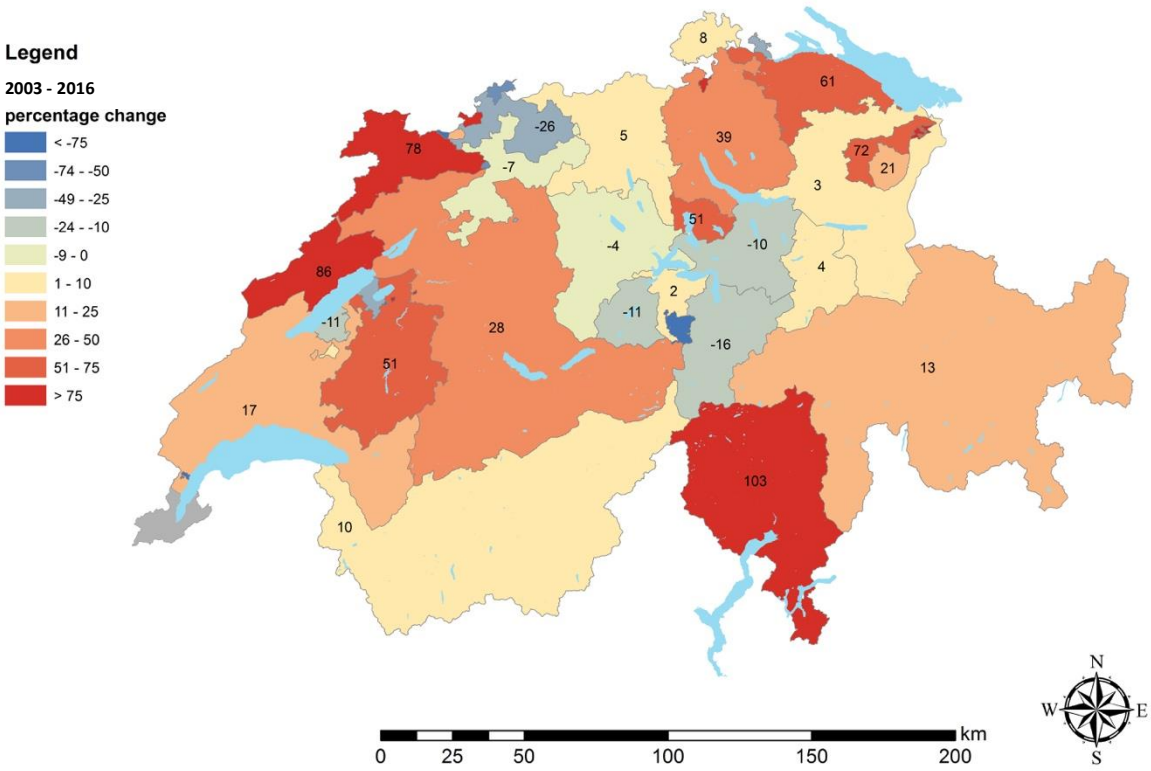

Figure S4: Percentage change for the apiary ‘density-index’ 2003-2016.

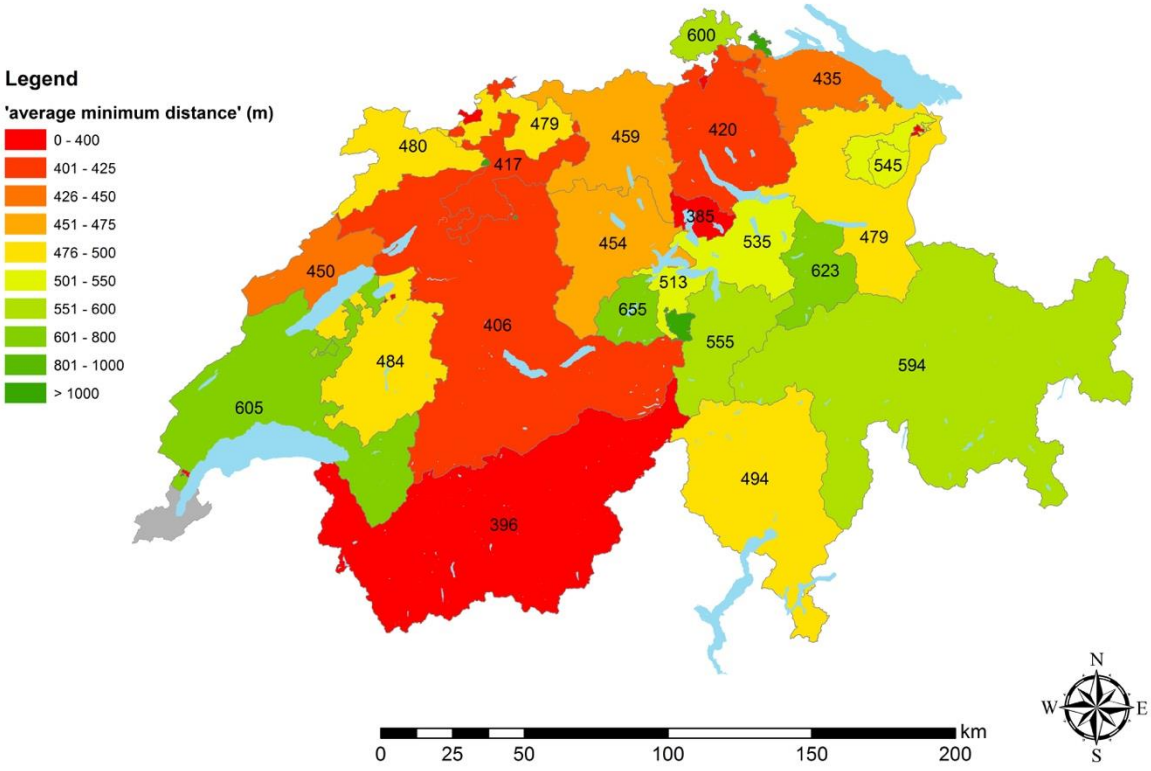

Figure S5: ‘Average minimum distance’ to the nearest apiary on cantonal level.

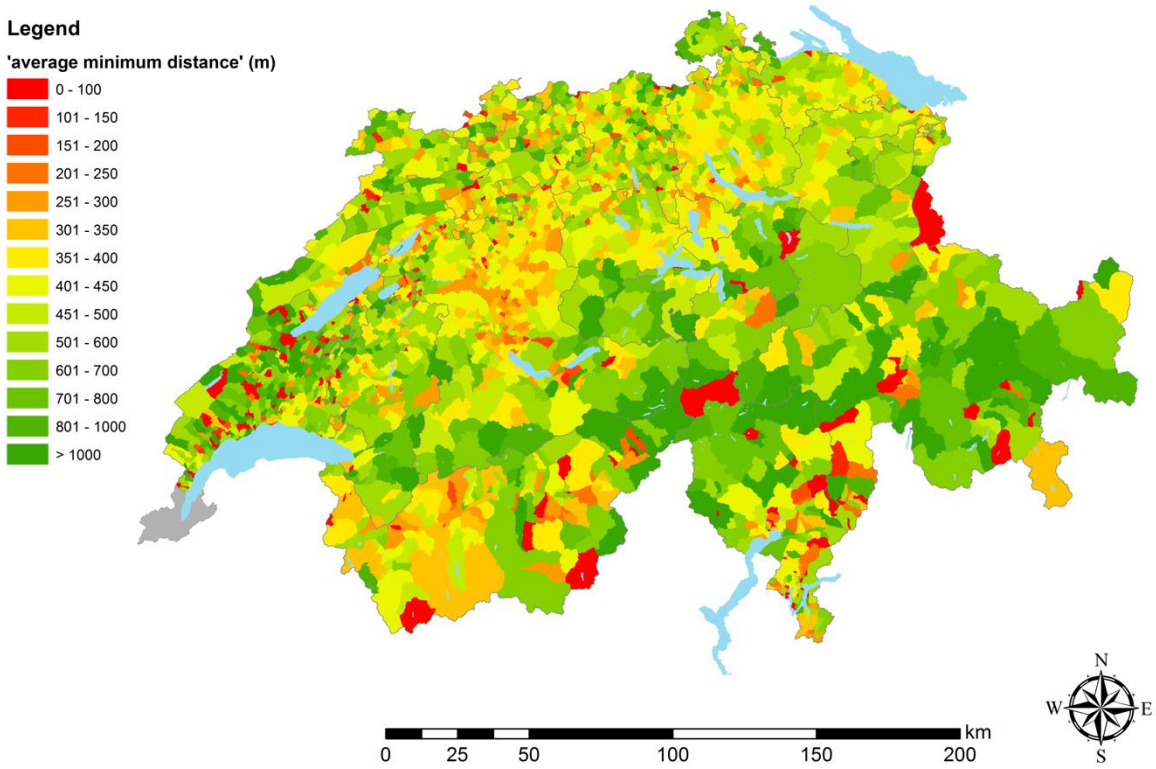

Figure S6: 'Average minimum distance' to the nearest apiary on municipal level.

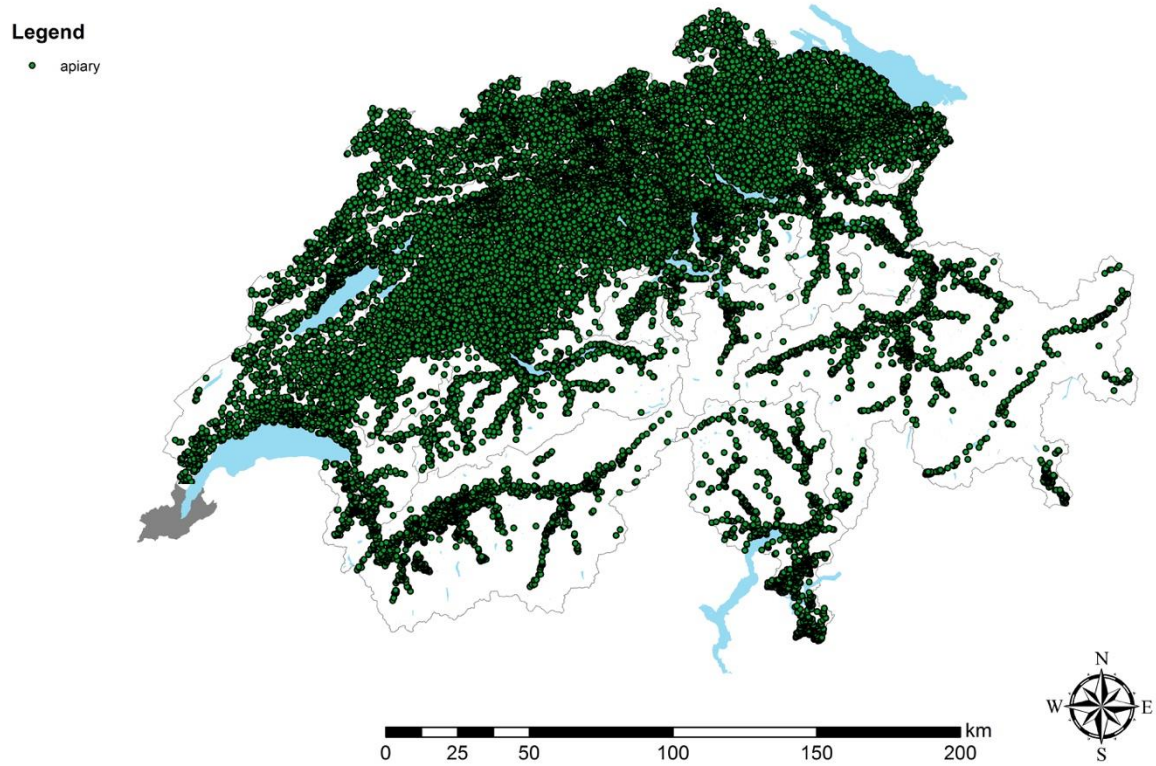

Figure S7: Active apiaries of Switzerland in the end of 2016: 23,055.

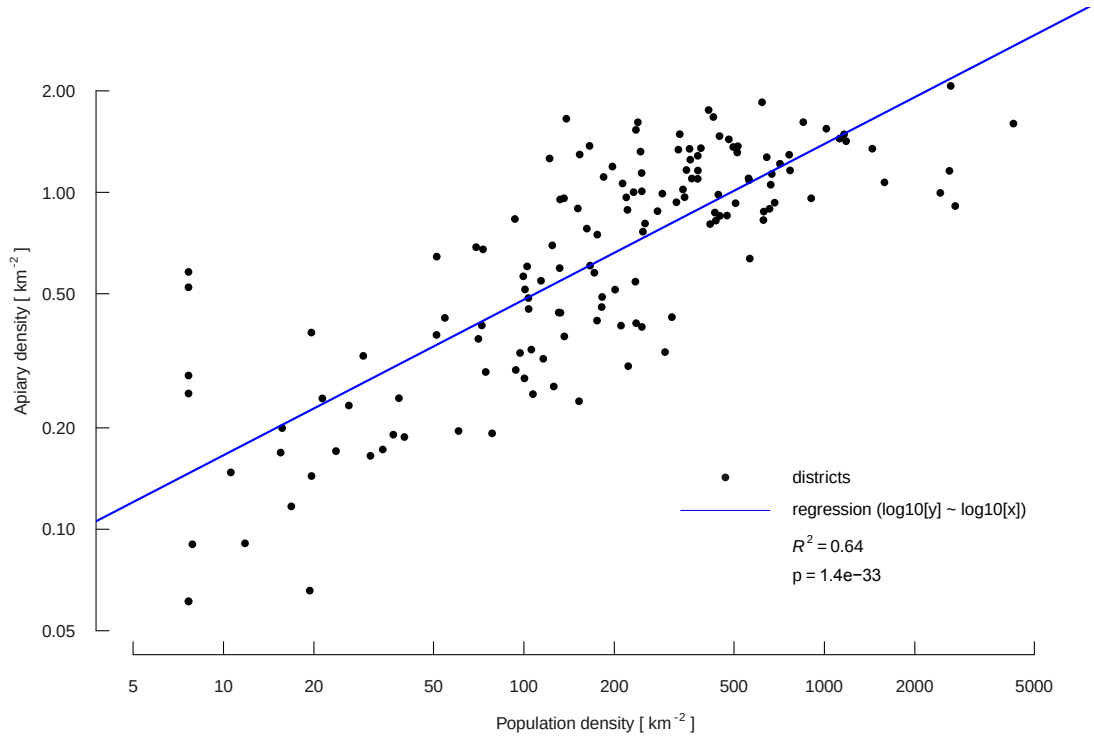

Figure S8: Scatter plot apiary density vs. human population density. Each data point is a district in Switzerland.

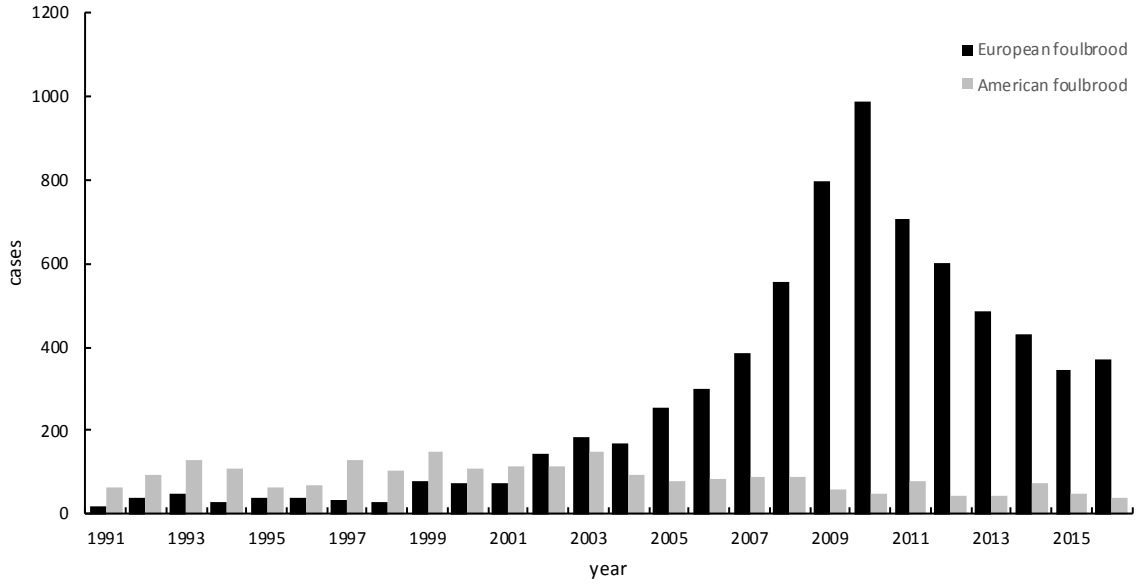

Figure S9: Bar plot of all AFB and EFB cases in Switzerland, summarized for the period 1991-2016.

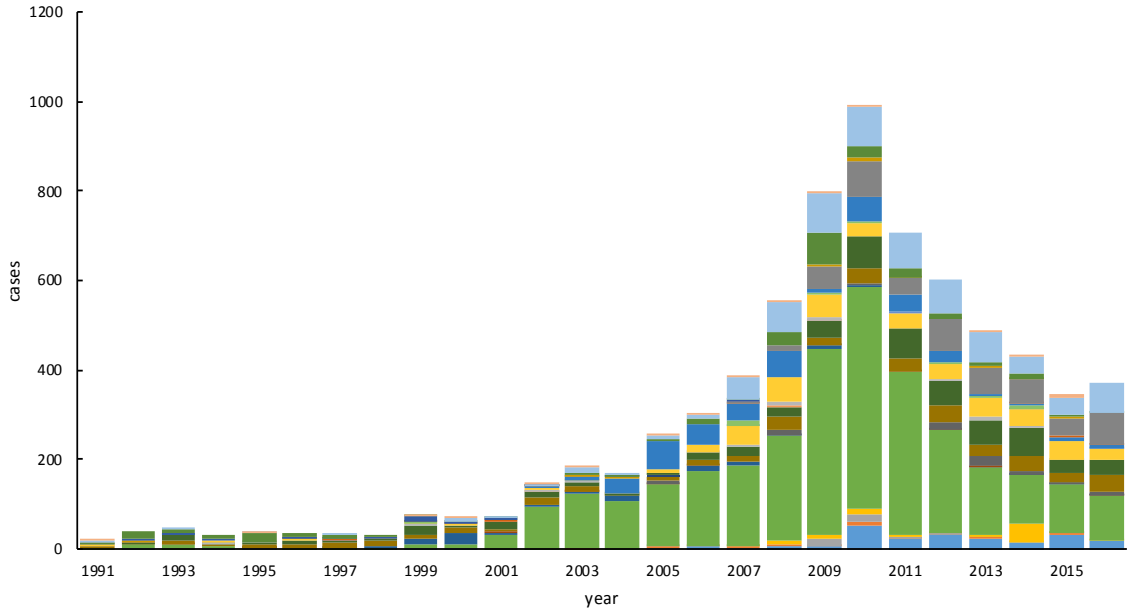

Figure S10: Bar plot of all EFB cases in Switzerland for the period 1991-2016. Different colors indicate different cantons. Light green is Bern, grey is Thurgau and light blue is Zurich.

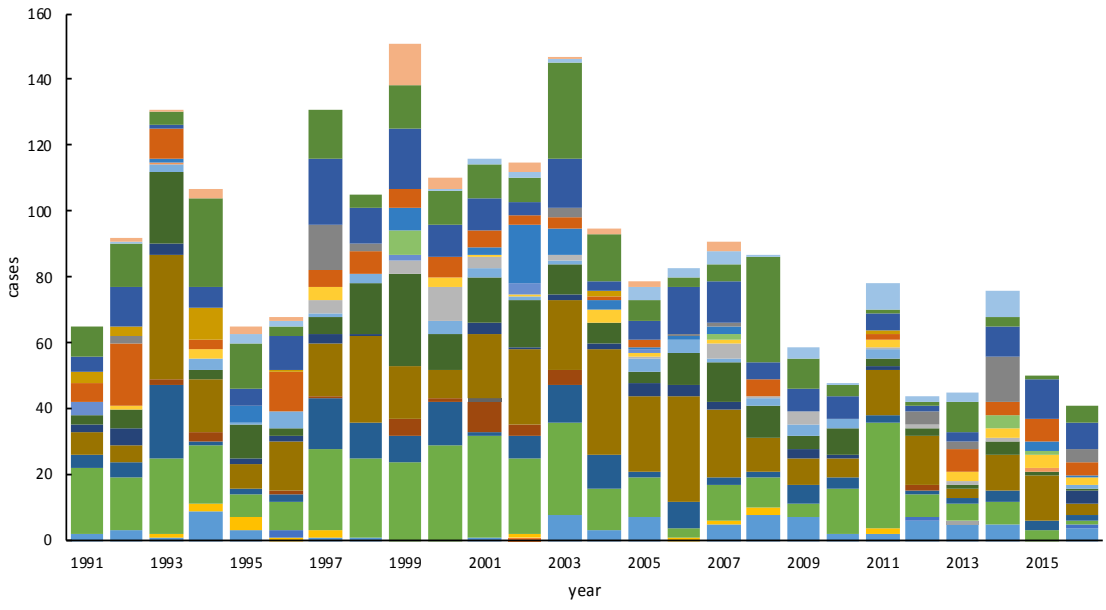

Figure S11: Bar plot of all AFB cases in Switzerland for the period 1991-2016. Different colors indicate different cantons. Light green is Bern, brown is Graubünden, and dark green is Lucerne.