**Supplementary Material**

Drivers of population change in common farmland birds in Germany

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Table S1. Details of species selection for analysis. Considered were all species using agriculturally characterized breeding and/or feeding habitats according to the German bird trait data base (Wahl *et al.* 2014). Precluded (and not part of the table below) were species with the breeding status “former breeding bird, now extinct” and “sporadic breeder” as well as species with the frequency class “extremely rare” according to the German Red List (Grüneberg *et al.* 2015). To the remaining set of species three selection criteria were applied.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **1. criterion** | | **2. criterion** | **3. criterion** |  |  |  |  |
|  |  | **habitat** | |  |  |  |  |  |  |
| **species (former and current breeding bird species)** | **scientific name** | **breeding habitat** | **feeding habitat during the breeding season** | **reliable population trends available at regional scale for at least 2 of the 3 classified German regions** | **most relevant suspected population change determining factors relate to agricultural practices** | **national farmland indicator species** | **sub-national indicator species** | **final species set** | **comment** |
| Greater Rhea | *Rhea americana* | arable fields and open land characterized by arable fields | arable fields and open land characterized by arable fields | no | n.a. | no |  |  |  |
| Greater Canada Goose | *Branta canadensis* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Barnacle Goose | *Branta leucopsis* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Swan Goose | *Anser cygnoides* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Snow Goose | *Anser caerulescens* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Bar-headed Goose | *Anser indicus* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Greylag Goose | *Anser anser* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Egyptian Goose | *Alopochen aegyptiaca* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Ruddy Shelduck | *Tadorna ferruginea* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Common Quail | *Coturnix coturnix* | arable fields and open land characterized by arable fields | arable fields and open land characterized by arable fields | no | n.a. | no |  |  |  |
| Common Pheasant | *Phasianus colchicus* | farmed open land (indifferent) | farmed open land (indifferent) | yes | no | no |  |  | population status mainly depends on releases of animals by hunters |
| White Stork | *Ciconia ciconia* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Lesser Spotted Eagle | *Aquila pomarina* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Montagu's Harrier | *Circus pygargus* | arable fields and open land characterized by arable fields | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Red Kite | *Milvus milvus* |  | farmed open land (indifferent) | no | n.a. | yes |  |  |  |
| Common Linnet | *Carduelis cannabina* |  | wasteland, ruderal and tall forb communities | yes | yes | no | yes | yes |  |
| Common Kestrel | *Falco tinnunculus* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Common Crane | *Grus grus* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Great Bustard | *Otis tarda* | farmed open land (indifferent) | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Corncrake | *Crex crex* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Northern Lapwing | *Vanellus vanellus* | farmed open land (indifferent) | farmed open land (indifferent) | yes | yes | yes |  | yes |  |
| Eurasian Curlew | *Numenius arquata* | grassland and open land characterized by grassland | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Black-tailed Godwit | *Limosa limosa* | grassland and open land characterized by grassland | grassland and open land characterized by grassland | yes | yes | yes |  | yes |  |
| Common Snipe | *Gallinago gallinago* | grassland and open land characterized by grassland | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Ruff | *Philomachus pugnax* | grassland and open land characterized by grassland | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Black-headed Gull | *Larus ridibundus* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Mediterranean Gull | *Larus melanocephalus* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Mew Gull | *Larus canus* |  | grassland and open land characterized by grassland | no | n.a. | no |  |  |  |
| Gull-billed Tern | *Gelochelidon nilotica* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Stock Dove | *Columba oenas* |  | farmed open land (indifferent) | yes | no | no |  |  | forest indicator species in several federal states, therefore not considered as farmland bird |
| European Turtle Dove | *Streptopelia turtur* |  | farmed open land (indifferent) | yes | yes | no |  | yes |  |
| Barn Owl | *Tyto alba* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Little Owl | *Athene noctua* | grassland and open land characterized by grassland | grassland and open land characterized by grassland | no | n.a. | yes |  |  |  |
| Long-eared Owl | *Asio otus* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Red-backed Shrike | *Lanius collurio* | farmed open land (indifferent) | farmed open land (indifferent) | yes | yes | yes |  | yes |  |
| Great Grey Shrike | *Lanius excubitor* | farmed open land (indifferent) | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Western Jackdaw | *Coloeus monedula* |  | farmed open land (indifferent) | yes | no | no |  |  | settlement indicator species at national level, therefore not considered as farmland bird |
| Rook | *Corvus frugilegus* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Common Whitethroat | *Sylvia communis* | farmed open land (indifferent) | farmed open land (indifferent) | yes | yes | no | yes | yes |  |
| Crested Lark | *Galerida cristata* | wasteland, ruderal and tall forb communities | wasteland, ruderal and tall forb communities | no | n.a. | no |  |  |  |
| Eurasian Skylark | *Alauda arvensis* | farmed open land (indifferent) | farmed open land (indifferent) | yes | yes | yes |  | yes |  |
| Common Grasshopper Warbler | *Locustella naevia* | wasteland, ruderal and tall forb communities | wasteland, ruderal and tall forb communities | yes | yes | no | yes | yes |  |
| River Warbler | *Locustella fluviatilis* | wasteland, ruderal and tall forb communities | wasteland, ruderal and tall forb communities | no | n.a. | no |  |  |  |
| Marsh Warbler | *Acrocephalus palustris* | wasteland, ruderal and tall forb communities | wasteland, ruderal and tall forb communities | yes | yes | no | yes | yes |  |
| Common Starling | *Sturnus vulgaris* |  | grassland and open land characterized by grassland | yes | yes | no |  | yes |  |
| Mistle Thrush | *Turdus viscivorus* |  | grassland and open land characterized by grassland | yes | yes | no |  | yes |  |
| Common Buzzard | *Buteo buteo* |  | farmed open land (indifferent) | no | n.a. | no |  |  |  |
| Fieldfare | *Turdus pilaris* |  | grassland and open land characterized by grassland | yes | yes | no |  | yes |  |
| Whinchat | *Saxicola rubetra* | grassland and open land characterized by grassland | grassland and open land characterized by grassland | yes | yes | yes |  | yes |  |
| Grey Partridge | *Perdix perdix* | arable fields and open land characterized by arable fields | arable fields and open land characterized by arable fields | no | n.a. | no |  |  |  |
| Blue-headed Yellow Wagtail | *Motacilla flava* | farmed open land (indifferent) | farmed open land (indifferent) | yes | yes | no | yes | yes |  |
| European Goldfinch | *Carduelis carduelis* |  | wasteland, ruderal and tall forb communities | yes | yes | no |  | yes |  |
| Corn Bunting | *Emberiza calandra* | farmed open land (indifferent) | wasteland, ruderal and tall forb communities | no | n.a. | yes |  |  |  |
| Yellowhammer | *Emberiza citrinella* | farmed open land (indifferent) | farmed open land (indifferent) | yes | yes | yes |  | yes |  |
| Cirl Bunting | *Emberiza cirlus* |  | wasteland, ruderal and tall forb communities | no | n.a. | no |  |  |  |
| Ortolan Bunting | *Emberiza hortulana* | arable fields and open land characterized by arable fields | arable fields and open land characterized by arable fields | no | n.a. | no |  |  |  |

Table S2. Model-averaged effect estimates for all farmland bird species analysed.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variable** | **Estimate** | **StdError** | **Pvalue** | **Species** |
| **(Intercept)** | 0.222 | 0.038 | <0.001 | Black-tailed Godwit |
| **RegionEast** | 0.251 | 0.054 | <0.001 | Black-tailed Godwit |
| **AreaGrassland** | -0.042 | 0.029 | 0.163 | Black-tailed Godwit |
| **AreaRapeseed** | -0.143 | 0.044 | 0.001 | Black-tailed Godwit |
| **AreaWinterWheat** | -0.208 | 0.045 | <0.001 | Black-tailed Godwit |
| **AvgTempApJul** | 0.041 | 0.032 | 0.211 | Black-tailed Godwit |
| **ColdSum** | -0.028 | 0.028 | 0.328 | Black-tailed Godwit |
| **IndexFallowMaize** | 0.060 | 0.040 | 0.147 | Black-tailed Godwit |
| **YieldWinterGrain** | -0.035 | 0.031 | 0.265 | Black-tailed Godwit |
| **(Intercept)** | 0.002 | 0.068 | 0.978 | Blue-head. Yel. Wagtail |
| **RegionEast** | 0.147 | 0.096 | 0.135 | Blue-head. Yel. Wagtail |
| **RegionSouthWest** | 0.180 | 0.096 | 0.068 | Blue-head. Yel. Wagtail |
| **AreaWinterWheat** | 0.123 | 0.065 | 0.060 | Blue-head. Yel. Wagtail |
| **AvgTempApJul** | -0.102 | 0.045 | 0.026 | Blue-head. Yel. Wagtail |
| **ColdSum** | 0.082 | 0.042 | 0.054 | Blue-head. Yel. Wagtail |
| **IndexFallowMaize** | 0.093 | 0.062 | 0.141 | Blue-head. Yel. Wagtail |
| **SahelRainfall** | 0.053 | 0.043 | 0.230 | Blue-head. Yel. Wagtail |
| **(Intercept)** | 0.375 | 0.058 | <0.001 | Com. Grasshopper Warbler |
| **RegionEast** | -0.108 | 0.072 | 0.142 | Com. Grasshopper Warbler |
| **RegionSouthWest** | -0.327 | 0.072 | <0.001 | Com. Grasshopper Warbler |
| **AreaGrassland** | -0.041 | 0.035 | 0.254 | Com. Grasshopper Warbler |
| **AreaWinterWheat** | -0.174 | 0.050 | 0.001 | Com. Grasshopper Warbler |
| **AvgRainApJul** | 0.031 | 0.035 | 0.392 | Com. Grasshopper Warbler |
| **AvgTempApJul** | -0.094 | 0.043 | 0.031 | Com. Grasshopper Warbler |
| **IndexFallowMaize** | 0.060 | 0.059 | 0.320 | Com. Grasshopper Warbler |
| **YieldWinterGrain** | -0.059 | 0.043 | 0.178 | Com. Grasshopper Warbler |
| **(Intercept)** | 0.350 | 0.038 | <0.001 | Common Linnet |
| **RegionEast** | -0.300 | 0.052 | <0.001 | Common Linnet |
| **RegionSouthWest** | 0.286 | 0.052 | <0.001 | Common Linnet |
| **AreaGrassland** | 0.117 | 0.026 | <0.001 | Common Linnet |
| **AreaRapeseed** | -0.061 | 0.039 | 0.125 | Common Linnet |
| **AreaWinterWheat** | -0.181 | 0.038 | <0.001 | Common Linnet |
| **AvgRainApJul** | 0.027 | 0.024 | 0.254 | Common Linnet |
| **AvgTempApJul** | -0.070 | 0.027 | 0.012 | Common Linnet |
| **ColdSum** | -0.043 | 0.023 | 0.069 | Common Linnet |
| **IndexFallowMaize** | 0.091 | 0.038 | 0.018 | Common Linnet |
| **YieldWinterGrain** | -0.033 | 0.028 | 0.256 | Common Linnet |
| **(Intercept)** | 0.385 | 0.035 | <0.001 | Common Starling |
| **RegionEast** | -0.199 | 0.050 | <0.001 | Common Starling |
| **RegionSouthWest** | -0.247 | 0.050 | <0.001 | Common Starling |
| **AreaGrassland** | 0.078 | 0.024 | 0.001 | Common Starling |
| **AreaRapeseed** | -0.046 | 0.026 | 0.086 | Common Starling |
| **AvgRainApJul** | 0.020 | 0.020 | 0.333 | Common Starling |
| **AvgTempApJul** | -0.044 | 0.021 | 0.042 | Common Starling |
| **IndexFallowMaize** | 0.134 | 0.027 | <0.001 | Common Starling |
| **(Intercept)** | -0.016 | 0.025 | 0.523 | Common Whitethroat |
| **RegionEast** | 0.098 | 0.028 | 0.001 | Common Whitethroat |
| **RegionSouthWest** | 0.165 | 0.028 | <0.001 | Common Whitethroat |
| **AreaGrassland** | -0.158 | 0.015 | <0.001 | Common Whitethroat |
| **AreaRapeseed** | -0.047 | 0.020 | 0.022 | Common Whitethroat |
| **AreaWinterWheat** | 0.046 | 0.026 | 0.080 | Common Whitethroat |
| **AvgRainApJul** | -0.017 | 0.015 | 0.277 | Common Whitethroat |
| **ColdSum** | -0.031 | 0.017 | 0.084 | Common Whitethroat |
| **IndexFallowMaize** | 0.043 | 0.028 | 0.137 | Common Whitethroat |
| **SahelRainfall** | 0.035 | 0.020 | 0.084 | Common Whitethroat |
| **(Intercept)** | 0.299 | 0.022 | <0.001 | Eurasian Skylark |
| **RegionEast** | -0.204 | 0.030 | <0.001 | Eurasian Skylark |
| **RegionSouthWest** | -0.132 | 0.030 | <0.001 | Eurasian Skylark |
| **AreaGrassland** | 0.091 | 0.016 | <0.001 | Eurasian Skylark |
| **AreaRapeseed** | -0.082 | 0.019 | <0.001 | Eurasian Skylark |
| **AreaWinterWheat** | -0.064 | 0.023 | 0.007 | Eurasian Skylark |
| **AvgRainApJul** | 0.025 | 0.014 | 0.076 | Eurasian Skylark |
| **AvgTempApJul** | 0.019 | 0.017 | 0.268 | Eurasian Skylark |
| **ColdSum** | -0.020 | 0.014 | 0.148 | Eurasian Skylark |
| **IndexFallowMaize** | 0.045 | 0.023 | 0.055 | Eurasian Skylark |
| **YieldWinterGrain** | -0.027 | 0.016 | 0.109 | Eurasian Skylark |
| **(Intercept)** | 0.203 | 0.043 | <0.001 | European Goldfinch |
| **RegionEast** | 0.086 | 0.061 | 0.163 | European Goldfinch |
| **RegionSouthWest** | 0.163 | 0.061 | 0.008 | European Goldfinch |
| **AreaGrassland** | -0.041 | 0.029 | 0.162 | European Goldfinch |
| **AreaRapeseed** | -0.050 | 0.038 | 0.200 | European Goldfinch |
| **AvgTempApJul** | -0.077 | 0.030 | 0.011 | European Goldfinch |
| **IndexFallowMaize** | 0.201 | 0.035 | <0.001 | European Goldfinch |
| **(Intercept)** | 0.480 | 0.052 | <0.001 | European Turtle Dove |
| **RegionEast** | -0.204 | 0.069 | 0.004 | European Turtle Dove |
| **RegionSouthWest** | -0.174 | 0.069 | 0.013 | European Turtle Dove |
| **AreaGrassland** | 0.154 | 0.035 | <0.001 | European Turtle Dove |
| **AreaRapeseed** | -0.085 | 0.049 | 0.091 | European Turtle Dove |
| **AvgTempApJul** | -0.088 | 0.039 | 0.029 | European Turtle Dove |
| **ColdSum** | -0.079 | 0.034 | 0.022 | European Turtle Dove |
| **IndexFallowMaize** | 0.270 | 0.050 | <0.001 | European Turtle Dove |
| **(Intercept)** | 0.379 | 0.040 | <0.001 | Fieldfare |
| **RegionEast** | -0.323 | 0.047 | <0.001 | Fieldfare |
| **RegionSouthWest** | -0.139 | 0.047 | 0.004 | Fieldfare |
| **AreaGrassland** | 0.206 | 0.025 | <0.001 | Fieldfare |
| **AreaRapeseed** | 0.045 | 0.036 | 0.220 | Fieldfare |
| **AreaWinterWheat** | -0.062 | 0.031 | 0.048 | Fieldfare |
| **AvgTempApJul** | -0.059 | 0.031 | 0.065 | Fieldfare |
| **ColdSum** | -0.037 | 0.028 | 0.195 | Fieldfare |
| **IndexFallowMaize** | 0.068 | 0.035 | 0.053 | Fieldfare |
| **(Intercept)** | 0.099 | 0.028 | <0.001 | Marsh Warbler |
| **RegionEast** | -0.186 | 0.034 | <0.001 | Marsh Warbler |
| **RegionSouthWest** | -0.019 | 0.034 | 0.589 | Marsh Warbler |
| **AreaGrassland** | 0.117 | 0.017 | <0.001 | Marsh Warbler |
| **AvgTempApJul** | -0.019 | 0.020 | 0.365 | Marsh Warbler |
| **IndexFallowMaize** | 0.054 | 0.022 | 0.018 | Marsh Warbler |
| **SahelRainfall** | 0.017 | 0.020 | 0.419 | Marsh Warbler |
| **YieldWinterGrain** | 0.026 | 0.019 | 0.177 | Marsh Warbler |
| **(Intercept)** | 0.103 | 0.041 | 0.015 | Mistle Thrush |
| **RegionEast** | -0.063 | 0.059 | 0.293 | Mistle Thrush |
| **RegionSouthWest** | -0.179 | 0.059 | 0.003 | Mistle Thrush |
| **AreaGrassland** | 0.038 | 0.027 | 0.167 | Mistle Thrush |
| **AreaRapeseed** | -0.062 | 0.036 | 0.094 | Mistle Thrush |
| **AreaWinterWheat** | 0.063 | 0.035 | 0.078 | Mistle Thrush |
| **AvgTempApJul** | 0.050 | 0.030 | 0.102 | Mistle Thrush |
| **IndexFallowMaize** | -0.055 | 0.039 | 0.166 | Mistle Thrush |
| **YieldWinterGrain** | 0.034 | 0.028 | 0.236 | Mistle Thrush |
| **(Intercept)** | 0.312 | 0.053 | <0.001 | Northern Lapwing |
| **RegionEast** | 0.213 | 0.068 | 0.002 | Northern Lapwing |
| **RegionSouthWest** | 0.047 | 0.068 | 0.503 | Northern Lapwing |
| **AreaGrassland** | 0.035 | 0.034 | 0.313 | Northern Lapwing |
| **AreaRapeseed** | -0.170 | 0.045 | <0.001 | Northern Lapwing |
| **AreaWinterWheat** | -0.202 | 0.054 | <0.001 | Northern Lapwing |
| **ColdSum** | -0.032 | 0.035 | 0.377 | Northern Lapwing |
| **IndexFallowMaize** | 0.119 | 0.055 | 0.033 | Northern Lapwing |
| **YieldWinterGrain** | -0.032 | 0.038 | 0.406 | Northern Lapwing |
| **(Intercept)** | -0.068 | 0.048 | 0.168 | Red-backed Shrike |
| **RegionEast** | 0.082 | 0.067 | 0.232 | Red-backed Shrike |
| **RegionSouthWest** | 0.101 | 0.067 | 0.141 | Red-backed Shrike |
| **AvgRainApJul** | 0.029 | 0.028 | 0.303 | Red-backed Shrike |
| **IndexFallowMaize** | 0.067 | 0.031 | 0.033 | Red-backed Shrike |
| **YieldWinterGrain** | 0.067 | 0.033 | 0.046 | Red-backed Shrike |
| **(Intercept)** | 0.543 | 0.044 | <0.001 | Whinchat |
| **RegionEast** | -0.396 | 0.062 | <0.001 | Whinchat |
| **AreaGrassland** | 0.138 | 0.033 | <0.001 | Whinchat |
| **AreaWinterWheat** | -0.179 | 0.033 | <0.001 | Whinchat |
| **SahelRainfall** | -0.045 | 0.032 | 0.173 | Whinchat |
| **(Intercept)** | 0.090 | 0.019 | 0.000 | Yellowhammer |
| **RegionEast** | -0.246 | 0.023 | 0.000 | Yellowhammer |
| **RegionSouthWest** | 0.014 | 0.023 | 0.557 | Yellowhammer |
| **AreaGrassland** | 0.144 | 0.012 | 0.000 | Yellowhammer |
| **AreaWinterWheat** | 0.046 | 0.021 | 0.033 | Yellowhammer |
| **AvgRainApJul** | 0.022 | 0.012 | 0.067 | Yellowhammer |
| **AvgTempApJul** | -0.023 | 0.017 | 0.176 | Yellowhammer |
| **ColdSum** | 0.022 | 0.012 | 0.087 | Yellowhammer |
| **IndexFallowMaize** | 0.034 | 0.019 | 0.081 | Yellowhammer |
| **YieldWinterGrain** | -0.027 | 0.014 | 0.069 | Yellowhammer |

Table S3. Bootstrapped effect estimates for the overall group farmland bird species analysed.

|  |  |  |
| --- | --- | --- |
| **Variable** | **Estimate** | **StdError** |
| **AvgRainApJul** | 0.020 | 0.010 |
| **AvgTempApJul** | -0.039 | 0.017 |
| **YieldWinterGrain** | -0.010 | 0.016 |
| **AreaGrassland** | 0.060 | 0.027 |
| **AreaRapeseed** | -0.070 | 0.021 |
| **AreaWinterWheat** | -0.072 | 0.038 |
| **IndexFallowMaize** | 0.086 | 0.022 |
| **ColdSum** | -0.019 | 0.017 |
| **SahelRainfall** | 0.015 | 0.024 |

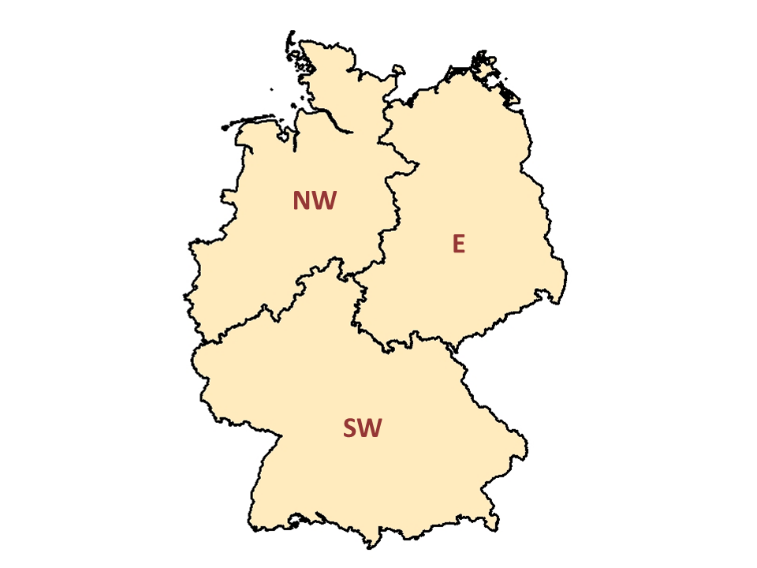


Figure S1. Germany divided into the three regions analysed (NW = northwest Germany, E = East Germany, SW = southwest Germany).

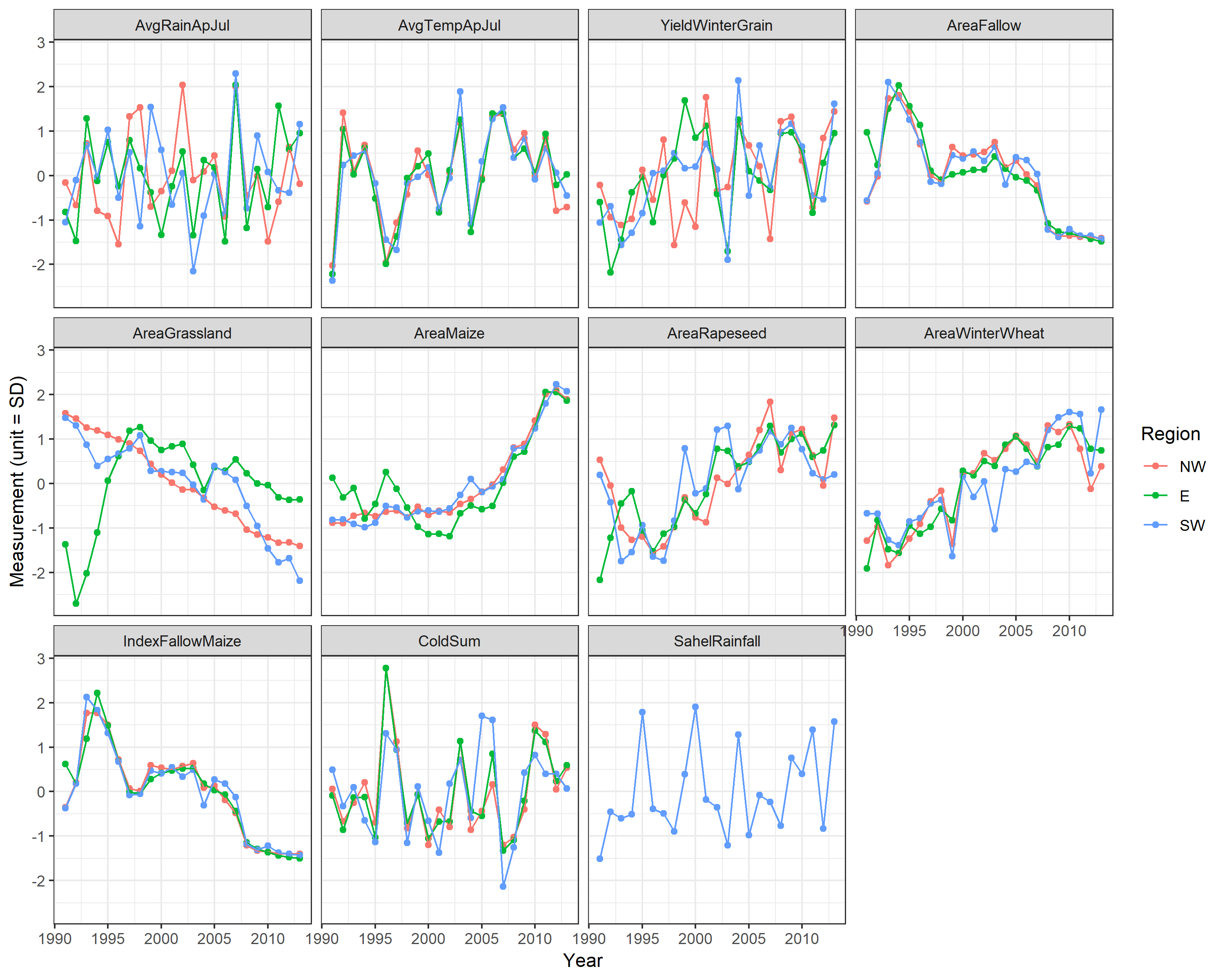


Figure S2.Values ofland-use and weather variables 1991-2013 used as predictors in the modelling framework, for the three regions considered. All variables were made comparable by centring and scaling (z-transformation) and thereby converted to units of phenotypic standard deviations (SD) around the mean.

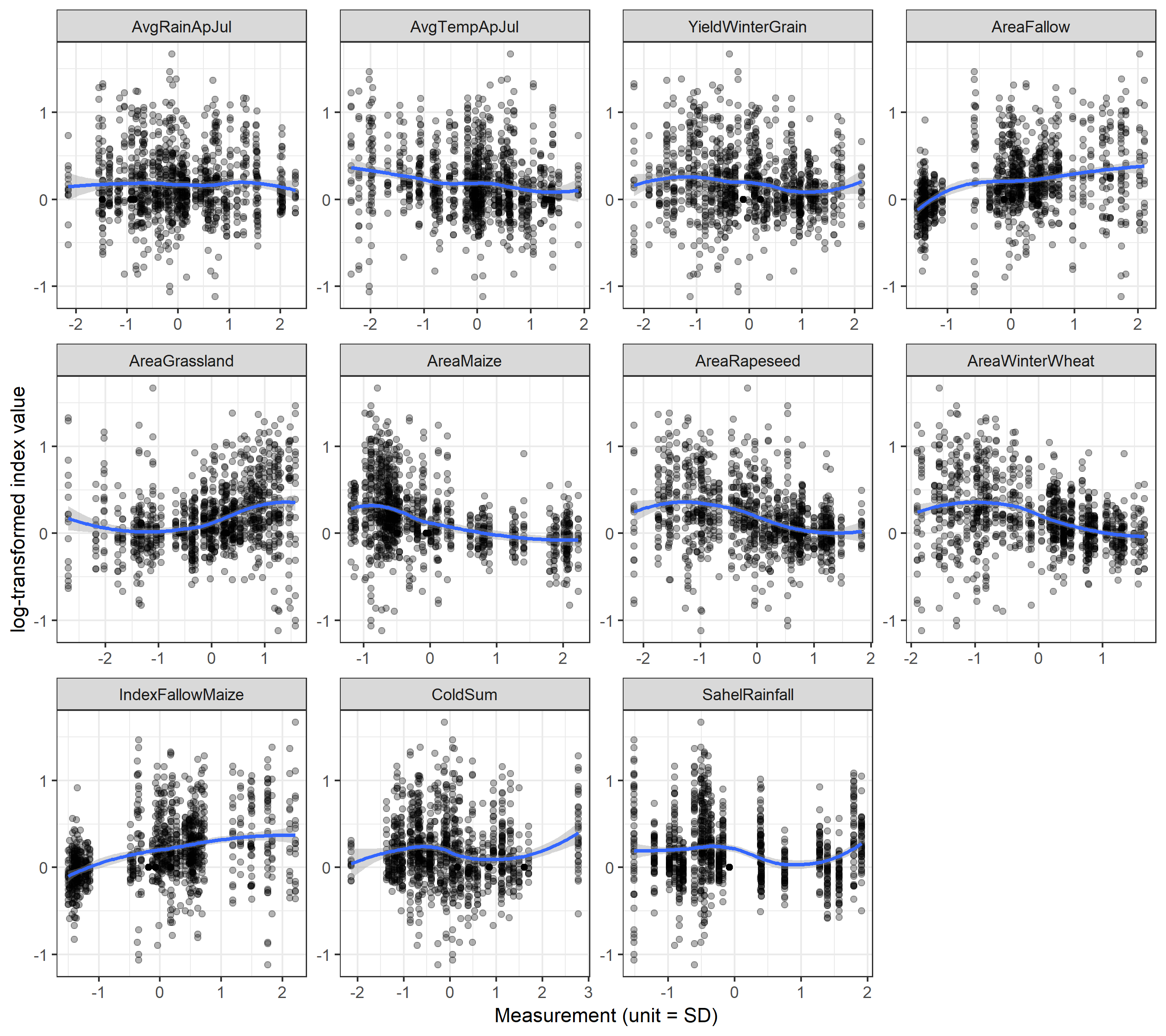


Figure S3. Relationship between log-transformed trend indices and explanatory variables for all farmland bird species in the analysis with time lag of 0 years. The blue line shows a loess smoother.

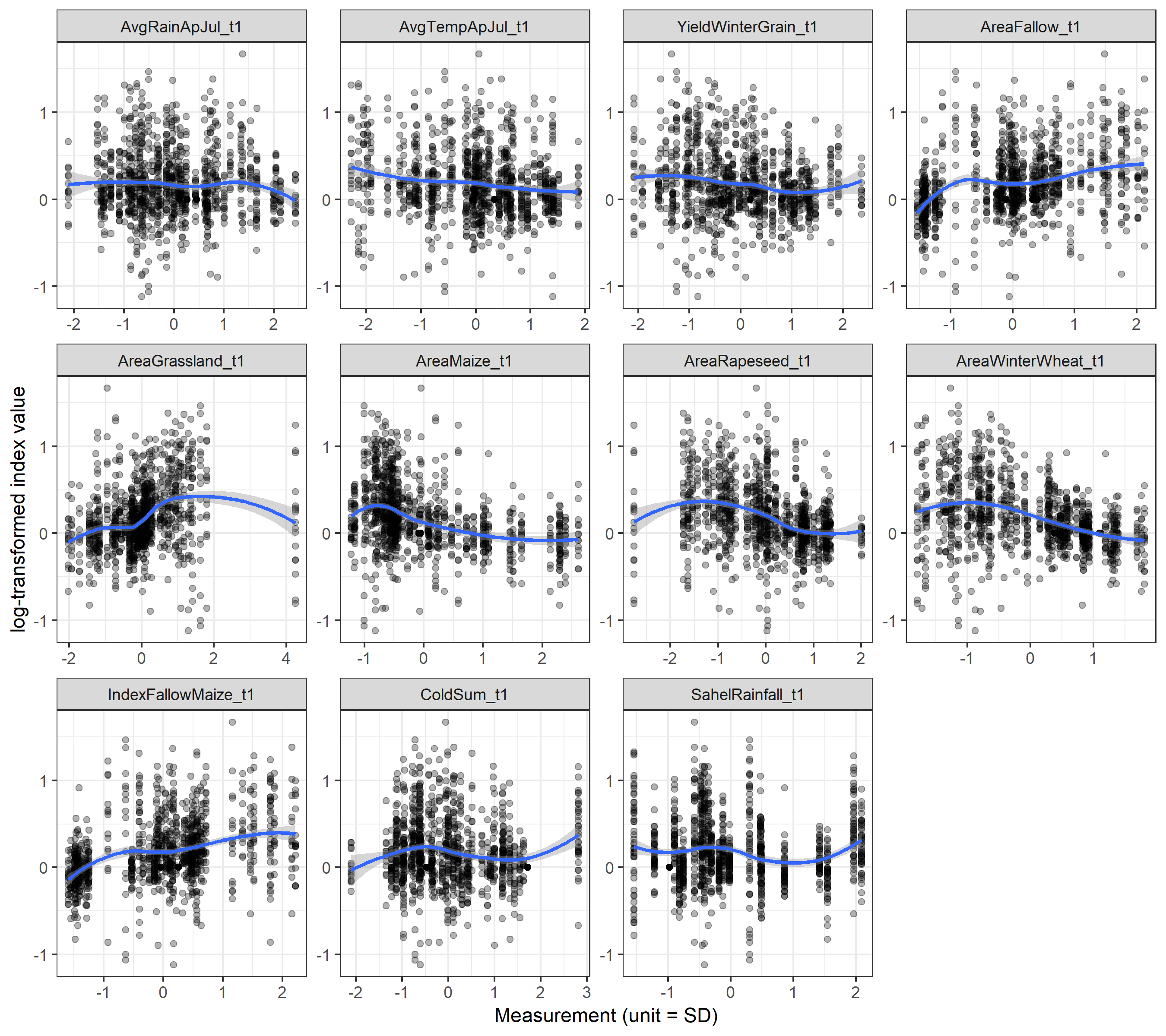


Figure S4. Relationship between log-transformed trend indices and explanatory variables for all farmland bird species in the analysis with time lag of 1 year. The blue line shows a loess smoother.