# S2 Text. Details on variables

## Overview

Table A. Overview of means, standard deviations and trends (for continuous variables if p < 0.05) of Y and X-Variables per region. Slope in the table heading refers to a linear regression over the data.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | FL | | | VK | | | ZE | | |
| Type of variable | Sub-category (1st) | Sub-category (2nd) | Abbreviation | Unit | Mean | SD | slope | Mean | SD | slope | Mean | SD | Slope |
| Response variables | Output efficiency | | OutputEff | € output/€ input | 112 | 24 | - | 105 | 22 | 0 | 102 | 24 | - |
|  |  |  | OutputEff\_resi | € output/€ input | 0.1 | 19.0 | - | 0.0 | 9.0 | - | -0.1 | 18.9 | - |
|  |  |  | OutputEff\_slope | €/€/year | 0.02 | 1.37 | 0.005 | 0.80 | 5.897 | -0.986 | -0.994 | 1.873 | - |
|  | Potato yield |  | PotatoYield | kg / ha | 48947 | 8472 | -334 | 42249 | 5525 | -242 | 43513 | 9780 | -464 |
|  |  |  | PotatoYield\_resi | kg / ha | 5 | 3465 | - | -10 | 4242 | - | -42 | 6130 | - |
|  |  |  | PotatoYield\_slope | kg / ha / year | -148 | 1146 | 3 | -251 | 1111 | - | -509 | 453 | - |
|  | Crop rotation energy yield | | CropRotYield | kJ / ha | 191228 | 35853 | 393 | 186749 | 25974 | - | 174478 | 29432 | - |
|  |  |  | CropRotYield\_resi | kJ / ha | 103 | 13197 | - | -222 | 16234 | - | -52 | 15516 | - |
|  |  |  | CropRotYield\_slope | kJ / ha / year | -114 | 8346 | -223 | 2290 | 3383 | -294 | 1144 | 3364 | - |
|  | Profit crops |  | ProfitCrops | €/ha | 5347 | 1726 | 119 | 1619 | 495 | - | 2868 | 1419 | -4 |
|  |  |  | ProfitCrops\_resi | €/ha | 8 | 1237 | - | -2 | 251 | - | -3 | 876 | - |
|  |  |  | ProfitCrops\_slope | € / ha / year | 99 | 105 | 2 | 48 | 140 | - | 3 | 46 | - |
|  | Nitrogen surplus | | Nsurplus | kg / ha | 107.8 | 61.1 | 4.2 | 96.8 | 42.6 | - | 121.9 | 58.3 | -0.1 |
|  |  |  | Nsurplus\_resi | kg/ha | 0.1 | 49.3 | - | 0.2 | 22.6 | - | -0.2 | 42.1 | - |
|  |  |  | Nsurplus\_slope | kg / ha / year | 3.4 | 5.8 | 0.2 | -3.3 | 14.1 | 0.7 | -0.7 | 5.8 | - |
|  |  |  |  |  | FL |  |  | VK |  |  | ZE |  |  |
| Type of variable | Sub-category (1st) | Sub-category (2nd) | Abbreviation | Unit | Mean | SD | slope | Mean | SD | slope | Mean | SD | Slope |
| Explanatory variable | Farm characteristics | Land use | AreaCereals | ha | 0.20 | 0.11 | 0.00 | 0.28 | 0.10 | - | 0.30 | 0.13 | - |
|  |  |  | AreaMainCrops | ha | 0.48 | 0.25 | - | 0.91 | 0.08 | - | 0.59 | 0.19 | - |
|  |  |  | TrueDiversity | # | 3.64 | 0.84 | -0.02 | 3.23 | 0.50 | - | 4.43 | 1.23 | - |
|  |  | Input intensity | Monetary input\* intensity | € input/cultivated ha | 7281 | 1581 | 154 | 3352 | 804 | 77 | 4560 | 1179 | 109 |
|  |  |  | Labour | AWU / cultivated ha | 0.03 | 0.01 | - | 0.01 | 0.007581 | - | 0.0166762 | 0.005852 | - |
|  |  |  | Crop Protection Product (CPP) | €/ cultivated ha | 607.3 | 145.4 | 19.3 | 394.0 | 104.4 | 15.1 | 435.1 | 156.4 | 13.2 |
|  |  |  | Nitrogen | €/ cultivated ha | 256.6 | 76.3 | - | 225.6 | 53.5 | - | 254.9 | 64.8 | 0.2 |
|  |  |  | Phosphate | €/ cultivated ha | 81.7 | 25.6 | -1.0 | 74.7 | 24.8 | - | 68.8 | 25.2 | -0.8 |
|  |  |  | Energy | €/ cultivated ha | 182.7 | 94.4 | - | 20.4 | 14.9 | - | 83.2 | 58.7 | 0.5 |
|  |  |  | TotalCostsperha\*\* | €/ cultivated ha | 2025.7 | 583.2 | 57.1 | 871.1 | 205.4 | 38.7 | 1398.8 | 592.4 | 41.9 |
|  |  | Management | FarmManagement | # managers / ha | 0.03 | 0.02 | -0.001 | 0.02 | 0.01 | - | 0.01 | 0.01 | 0.0002 |
|  |  |  | AgeFarmer | Years | 52.8 | 8.6 | - | 54.8 | 9.3 | 0.2 | 48.3 | 9.2 | 0.7 |
|  |  |  | OtherRevenue | €/ cultivated ha | 1136 | 726 | - | 1081 | 494 | 3 | 738 | 335 | 16 |
|  |  | Assets | Area | ha | 120.1 | 105.9 | 2.5 | 130.3 | 109.4 | 4.7 | 127.8 | 53.8 | - |
|  |  |  | AreaOwned | owned ha / total ha | 0.58 | 0.27 | - | 0.76 | 0.24 | - | 0.61 | 0.31 | - |
|  |  |  | OwnCapital | € own / € total assets | 66.3 | 19.4 | - | 76.6 | 13.4 | - | 80.4 | 10.3 | - |
|  |  |  |  |  | FL |  |  | VK |  |  | ZE |  |  |
| Type of variable | Sub-category (1st) | Sub-category (2nd) | Abbreviation | Unit | Mean | SD | slope | Mean | SD | slope | Mean | SD | Slope |
|  |  |  | ModernityBuildings | # (0-100) | 45.4 | 15.2 | -0.4 | 43.7 | 17.5 | - | 48.2 | 17.6 | - |
|  |  |  | ModernityMachines | # (0-100) | 37.9 | 11.6 | - | 38.4 | 11.9 | -0.2 | 36.2 | 11.0 | -0.7 |
|  |  |  | Depreciation | € / cultivated ha | 1261 | 503 | 65 | 488 | 231 | 29 | 676 | 372 | 42 |
|  | Weather conditions | Average | Tempreature\_Spring | degree Celcius | 13.3 | 1.1 | - | 13.0 | 1.1 | - | 13.6 | 1.0 | - |
|  |  |  | Precipitation\_Spring | mm / day | 1.6 | 0.5 | - | 1.6 | 0.4 | - | 1.6 | 0.5 | - |
|  |  |  | PrecDef\_Spring | mm / day | 1.5 | 0.6 | - | 1.5 | 0.6 | - | 1.5 | 0.7 | - |
|  |  |  | Tempreature\_Summer | degree Celcius | 17.1 | 0.8 | - | 16.9 | 0.7 | - | 17.7 | 0.8 | - |
|  |  |  | Precipitation\_Summer | mm / day | 2.6 | 0.8 | - | 2.3 | 0.7 | - | 2.3 | 0.7 | - |
|  |  |  | PrecDef\_Summer | mm / day | 0.3 | 1.0 | - | 0.6 | 0.9 | - | 0.8 | 0.9 | - |
|  |  |  | Temperature | degree celcius | 10.6 | 0.7 | - | 10.3 | 0.7 | - | 11.4 | 0.7 | - |
|  |  |  | Precipitation | mm / day | 2.1 | 0.3 | - | 2.0 | 0.3 | - | 2.0 | 0.2 | - |
|  |  |  | PrecDef | mm / day | -0.2 | 0.3 | - | -0.1 | 0.4 | - | 0.0 | 0.3 | - |
|  |  | Extremes\*\*\* | ExtPrec45\_1 | # / 14 year | 0 |  |  | 0 |  |  | 0 |  |  |
|  |  |  | ExtPrec60\_3 | # / 14 year | 1 |  |  | 0 |  |  | 2 |  |  |
|  |  |  | HWave | # / 14 year | 6 |  |  | 8 |  |  | 4 |  |  |
|  |  |  | Frost | # / 14 year | 0 |  |  | 0 |  |  | 0 |  |  |
|  |  |  |  |  | FL |  |  | VK |  |  | ZE |  |  |
| Type of variable | Sub-category (1st) | Sub-category (2nd) | Abbreviation | Unit | Mean | SD | slope | Mean | SD | slope | Mean | SD | Slope |
|  |  |  | WarmWinter | # / 14 year | 5 |  |  | 4 |  |  | 9 |  |  |
|  |  |  | WarmWet | # / 14 year | 17 |  |  | 12 |  |  | 19 |  |  |
|  |  |  | D\_Spring | # / 14 year | 2 |  |  | 2 |  |  | 2 |  |  |
|  |  |  | D\_Summer | # / 14 year | 3 |  |  | 2 |  |  | 4 |  |  |
|  |  |  | WetHumPlant | # / 14 year | 29 |  |  | 22 |  |  | 32 |  |  |
|  |  |  | WetHumGrow | # / 14 year | 15 |  |  | 17 |  |  | 14 |  |  |
|  |  |  | WetHumHarv | # / 14 year | 13 |  |  | 12 |  |  | 11 |  |  |
|  | Market\*\*\*\* |  | OilPrice | €/ 100 L | 88 | 17 | 3 | 88 | 17 | 3 | 88 | 17 | 3 |
|  |  |  | FertilizerPrice | €/ 100 kg | 43 | 8 | - | 43 | 8 | - | 43 | 8 | - |
|  |  |  | LandPrice | €/ha | 57194 | 8065 | 1786 | 57194 | 8065 | 1786 | 57194 | 8065 | 1786 |
|  |  |  | Interest rate | % | 2.1 | 1.6 | -0.4 | 2.1 | 1.6 | -0.4 | 2.1 | 1.6 | -0.4 |

\*Monetary input at farm level, i.e. all fixed and variable costs.\*\*Cultivation costs, i.e. variable costs for crop cultivation. \*\*\*See Table A2.3 for more information. \*\*\*\*See Table A2.2 for more information

## Market conditions

Table B. Absolute values of market indicators included in the analyses: interest rate [35], oil price [33], fertilizer price [33] and land price [34].

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Land price (€/ha) | Interest rate (%) | Oil Price (€/ 100 L) | Fertilizer price (€/ 100 kg) |
| 2006 | 44506 | 3.78 | 64 | 27.35 |
| 2007 | 48076 | 4.29 | 65 | 27.75 |
| 2008 | 54967 | 4.23 | 81 | 48.00 |
| 2009 | 53183 | 3.69 | 61 | 61.50 |
| 2010 | 53856 | 2.99 | 74 | 41.25 |
| 2011 | 52339 | 2.99 | 90 | 44.00 |
| 2012 | 50964 | 1.93 | 96 | 45.55 |
| 2013 | 53809 | 1.96 | 110 | 45.05 |
| 2014 | 56758 | 1.45 | 109 | 44.65 |
| 2015 | 60644 | 0.69 | 94 | 47.00 |
| 2016 | 65695 | 0.29 | 87 | 46.60 |
| 2017 | 65480 | 0.52 | 94 | 42.45 |
| 2018 | 69004 | 0.58 | 103 | 41.95 |
| 2019 | 71440 | -0.07 | 105 | 42.95 |

## Weather extremes

Average weather conditions were calculated based on a 25x25km grid weather data from Agri4cast. The overlay of 25\*25km grids with the case study regions was calculated using ArcGIS-pro. A weighted average based on the calculated overlay was used to calculate the weather conditions for the case study areas. Average weather conditions included in the analysis were average temperature (degree Celsius), average daily precipitation (mm/day) and average daily precipitation deficit (mm/day) for the whole year, spring (April-June) and summer (July-September). The precipitation deficit is calculated as the amount of precipitation minus the daily reference evapotranspiration as provided by the Agri4cast data.

Table C. Weather extremes for potato production based on the AgroClimateCalendar. Source: adapted from Schaap et al. (2011, 2013).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Extreme event | Abbreviation | Period | Definition | Effect |
| Extreme precipitation | ExtPrec45\_1 or ExtrPrec60\_3 | May-September | >45 mm in 1 day or >60 mm in 2 days | Water logging and rotting of tubers |
| Wet/humid planting phase | WetHumPlant | October-April | > 0.75 mm / day for 21 subsequent days | Problems with sowing green manure and planting seed potatoes |
| Wet/humid growing phase | WetHumGrow | May-August | > 0.75 mm / day for 21 subsequent days | Difficulties spraying against phytophtora |
| Wet/humid harvesting phase | WetHumHarv | August-October | > 0.75 mm / day for 21 subsequent days | Difficulties harvesting the crop |
| Heatwave | HWave | July-August | > 25 0C for 5 days of which 3 days > 30 0C | Second growth reducing yield and quality |
| Late frost | Frost | April-May | < -2 0C for 2 subsequent days | Damage of young crop |
| Warm winter | WarmWinter | December-March | > 10 0C for 14 subsequent days | More rotting of  tubers in storage and early  sprouting in March |
| Warm and wet | WarmWet | July-September | > 20 0C and > 0 mm / day for 14 subsequent days | Increased prevalence of plant disease |
| Drought in spring\* | D\_Spring | February-April | < 5 mm precipitation in 30 subsequent days | Water stress affecting general plant development |
| Drought in summer\* | D\_Summer | May-September | < 10 mm precipitation in 30 subsequent days | Water stress affecting tuber development |

\*Originally drought was not included in the ACC as an extreme event for potato production in the Netherlands.

Table D. Occurrence of weather extremes in the three case studies from 2006 till 2019.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Region** | **ExtPrec**  **45\_1** | **ExtPrec**  **60\_3** | **HWave** | **Frost** | **Warm**  **Winter** | **Warm**  **Wet** | **D\_**  **Spring** | **D\_**  **Summer** | **WetHum**  **Plant** | **WetHum**  **Grow** |
| 2006 | FL | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 1 | 1 | 2 |
| 2007 | FL | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 4 | 2 |
| 2008 | FL | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 2009 | FL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2010 | FL | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 2 | 1 |
| 2011 | FL | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 2 |
| 2012 | FL | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 1 |
| 2013 | FL | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 4 | 1 |
| 2014 | FL | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 2 | 1 |
| 2015 | FL | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 3 | 0 |
| 2016 | FL | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 3 | 2 |
| 2017 | FL | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2018 | FL | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 4 | 0 |
| 2019 | FL | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 1 | 1 |
| 2006 | VK | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 2 | 2 |
| 2007 | VK | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 |
| 2008 | VK | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| 2009 | VK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2010 | VK | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 1 | 2 | 1 |
| 2011 | VK | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| 2012 | VK | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 |
| 2013 | VK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| 2014 | VK | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 3 | 2 |
| 2015 | VK | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 1 |
| 2016 | VK | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 2 |
| 2017 | VK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2018 | VK | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 2 | 0 |
| 2019 | VK | 0 | 0 | 2 | 0 | 1 | 2 | 0 | 0 | 1 | 2 |
| 2006 | ZE | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 2 |
| 2007 | ZE | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 2 |
| 2008 | ZE | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 2 |
| 2009 | ZE | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| 2010 | ZE | 0 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 0 |
| 2011 | ZE | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 1 |
| 2012 | ZE | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 2 | 2 |
| 2013 | ZE | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 |
| 2014 | ZE | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 3 | 1 |
| 2015 | ZE | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 1 |
| 2016 | ZE | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 3 | 1 |
| 2017 | ZE | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 |
| 2018 | ZE | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 3 | 0 |
| 2019 | ZE | 0 | 0 | 2 | 0 | 1 | 2 | 0 | 1 | 3 | 1 |