Farmers as water managers

Agro-meteorological Indicators of Climate Change

Aquarius Project Farmers Meeting
Tarland, 9th March 2010

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Further information: http://www.macaulay.ac.uk/aquarius/

Who Are We?

We are a research team from The Macaulay Institute in Aberdeen. Our work focuses on the impact that changes in policy and climate can have on agricultural systems. In Aquarius we are working with Aberdeenshire Council to understand the current and future risks of flooding and how to manage these risks in partnership with land managers.

Agro-meteorological Indicators

Indicators are pieces of information that can be used by managers to make decisions about the system (e.g. farm, estate, water-catchment, etc) that they manage.

Our agro-meteorological indicators are derived from weather and soils data and are intended to be useful for the agricultural industry. We produce two sets of indicators – one using observed climate data and one using future climate data. By comparing the outputs we illustrate how things may change in the future.

Observed Climate Data

The Met Office provides us with daily weather data for sites across the UK. The examples in this document use the observation period **1963-1980, 1995-2006**. Note the break in the data between 1981 and 1994.

The document presents the indicators for **Tarland**, however the nearest met station did not have sufficient data so we needed to prepare a composite data-set from the most suitable met stations in the surrounding area[1].

Future Climate Data

In order to make predictions of future patterns of weather we use the results from the Hadley Centre Regional Climate Model (HadRM3) using the medium-high CO_2 emissions scenario (known as A2c) for cell 4272 and the period **2071-2100**. There are other scenarios (low, medium-low and high) but we consider the medium-high to be the most likely. In forthcoming analyses we intend to update this approach with the recent UKCIP climate projections.

Rate of Change

There is a lot of uncertainty surrounding future climate predictions. Our assumption of medium-high emissions gives results for the period 2071-2100 but it is important to note that if emissions were to be higher then changes in climate could occur more rapidly.

Location of Sites

Figure 1 shows the location of the sites that are discussed in this document.

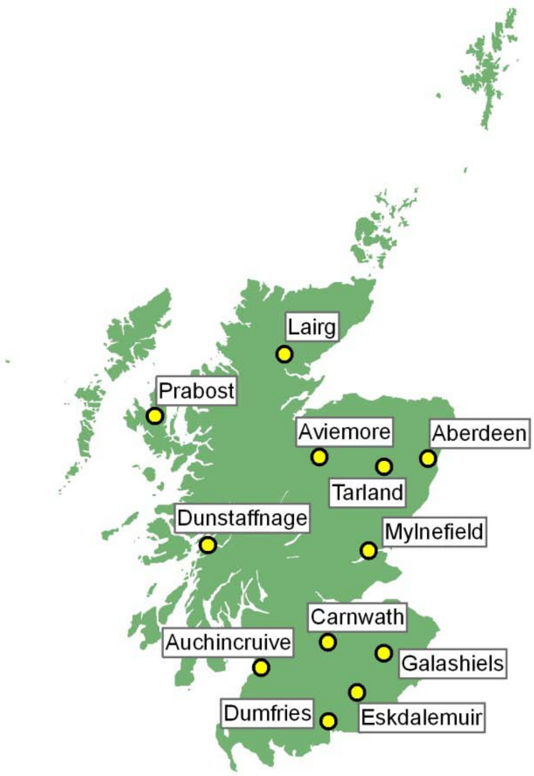

Figure 1: Map of SitesAverage Daily Temperature

[1] based on met stations at Tarland, Aboyne, Dinnet, Glen Tanar, Cushnie (Westfield), Tullynessle, Balmoral

Average Daily Temperature

It is widely accepted that temperature will increase with climate change. Figure 2 shows this change in a format that you will probably be familiar with. Note that our charts show observed data in blue while the future data is shown in red.

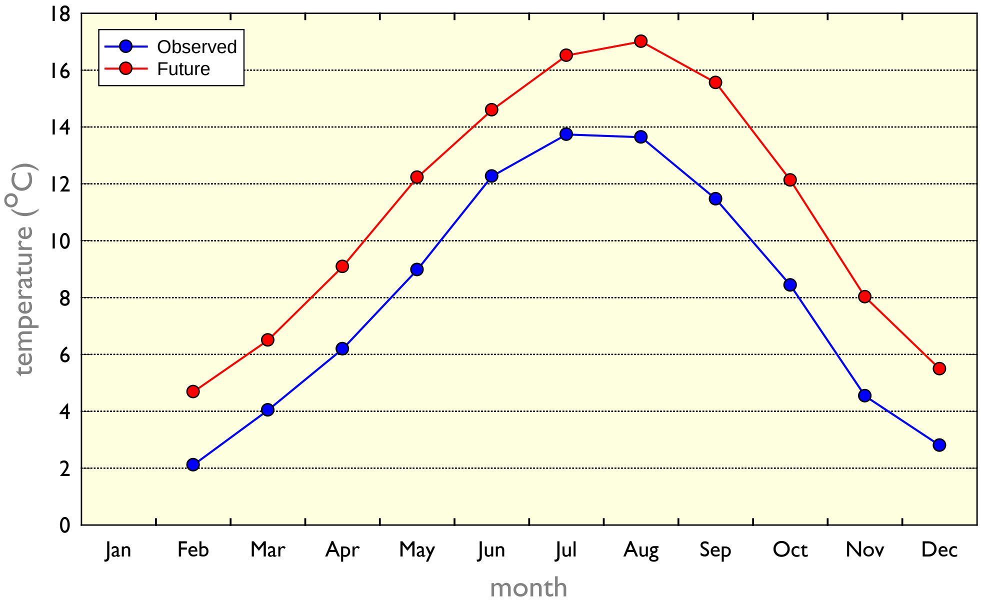

Figure 2: Average Daily Temperature by Month

This chart shows a rise in average temperature of around 3 degrees. For Scottish farming this may be viewed as a positive impact since it may improve yields or even allow for the introduction of new crops or varieties further north than is possible at the moment.

Next consider rainfall…

Average Monthly Rainfall

Our research shows that some sites will have more rain, some less and some will remain about the same. Perhaps more importantly we have discovered that there may be a seasonal shift in the rain pattern for some sites. For instance, in the future Tarland might expect an increase in rainfall during springtime and a decrease in late summer/early autumn (Figure 3).

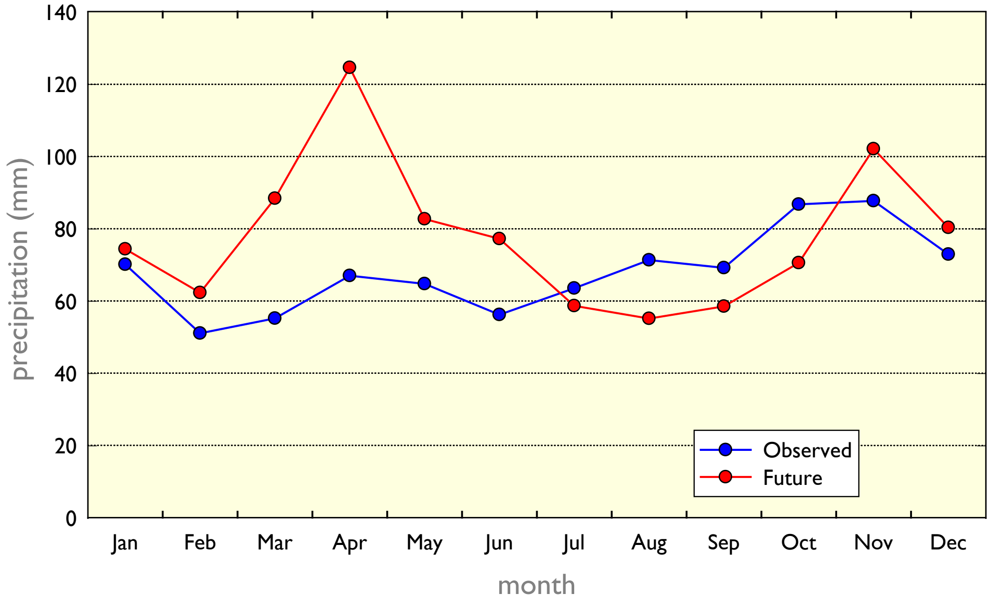

Figure 3: Average Monthly Rainfall

Large amounts of rain falling at certain times of year will clearly have implications for some livestock and field operations. It will also have implications for how often and how large any flooding events may be.

If we consider only temperature and rainfall charts it can be difficult to establish the extent to which these changes will affect agricultural systems at different times during the year. For this reason we have developed a set of more specialised indicators that show information that we hope is more relevant to the decision making process.

Growing Season

Our definition of a *growing day* is any day where the average temperature is above the base temperature (5.5 °C). The *start of the growing season* is the first date at which five growing days occur in a row. Similarly the *end of the growing season* is the last date at which five growing days occur in a row. Figure 4 is a yearly chart that shows the start and end dates of the growing season.

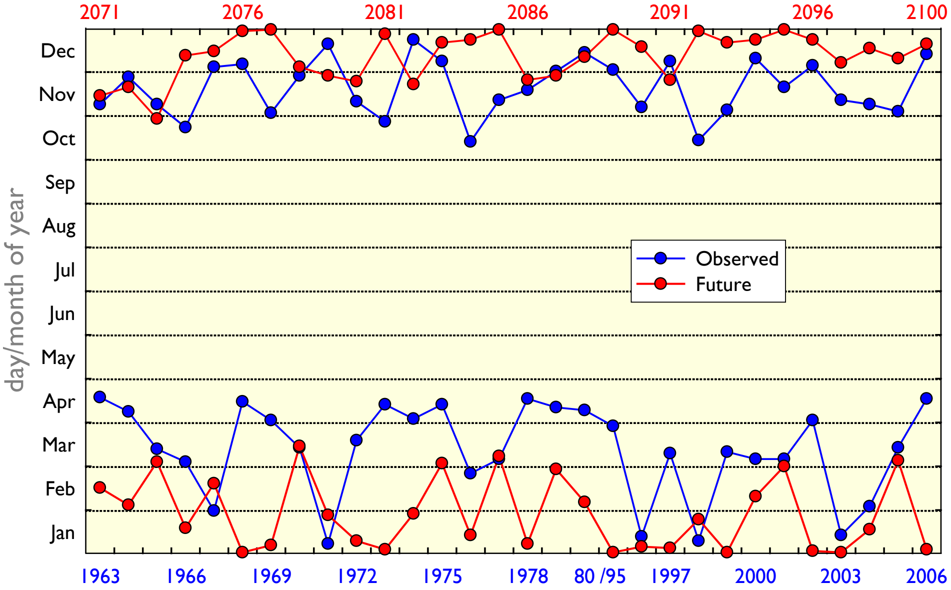

Figure 4: Start and End of the Growing Season

On average the start of the growing season is 45 days earlier while the end of the growing season is around 22 days later. Figure 5 shows the average number of days that the temperature is above the growing base temperature. Considering temperature only, this chart shows that there will be the potential for significantly more growth in spring and winter.

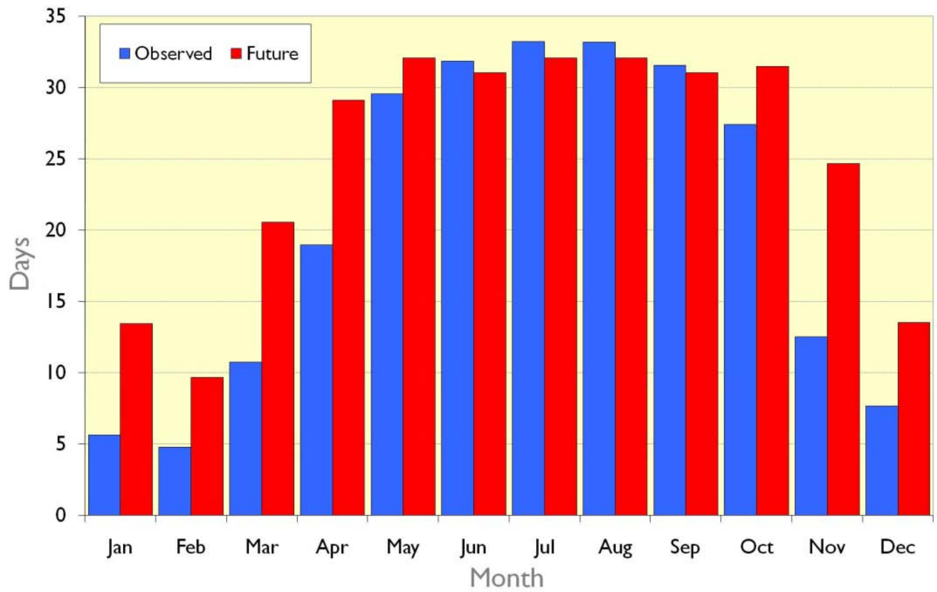

Figure 5: Growth Days by Month

Start of Field Operations

The $T_{sum}200$ indicator is commonly used to determine the start of field operations (e.g. the date of the first fertiliser application). It is calculated as the date (starting January 1st) at which the accumulated positive average temperature reaches 200 °C.

Figure 6 shows that on average the $T_{sum}200$ date will occur 27 days earlier in the future.

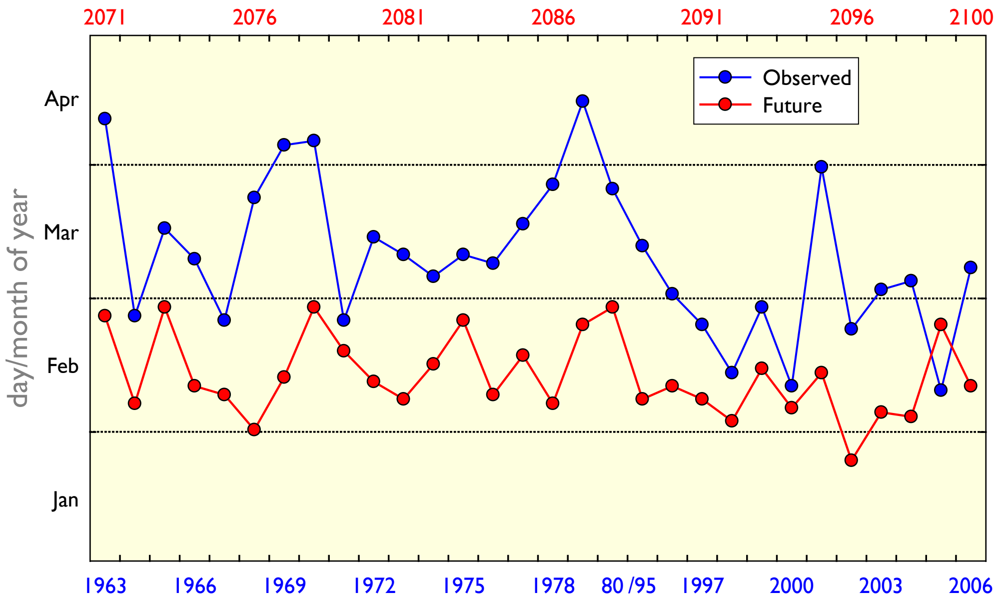

Figure 6: Tsum200

Frost

Figure 7 shows the dates of the last spring air frost. The observed data-set shows that a late frost in May or even June is commonplace while the future data-set shows that the last air frost will occur in March or April – on average 45 days earlier.

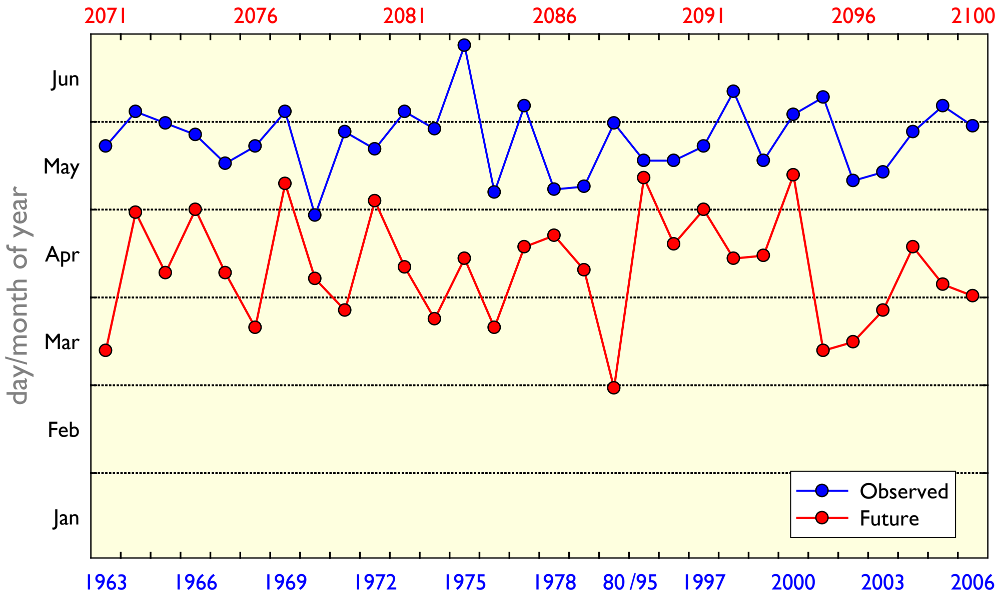

Figure 7: Last Spring Air Frost

It is thought that a "good hard frost" is a farmers ally in protecting against pests and diseases; however Figure 8 shows that the average number of frost days is in decline. We define a frost day when the minimum daily air temperature drops to or below 0^oC.

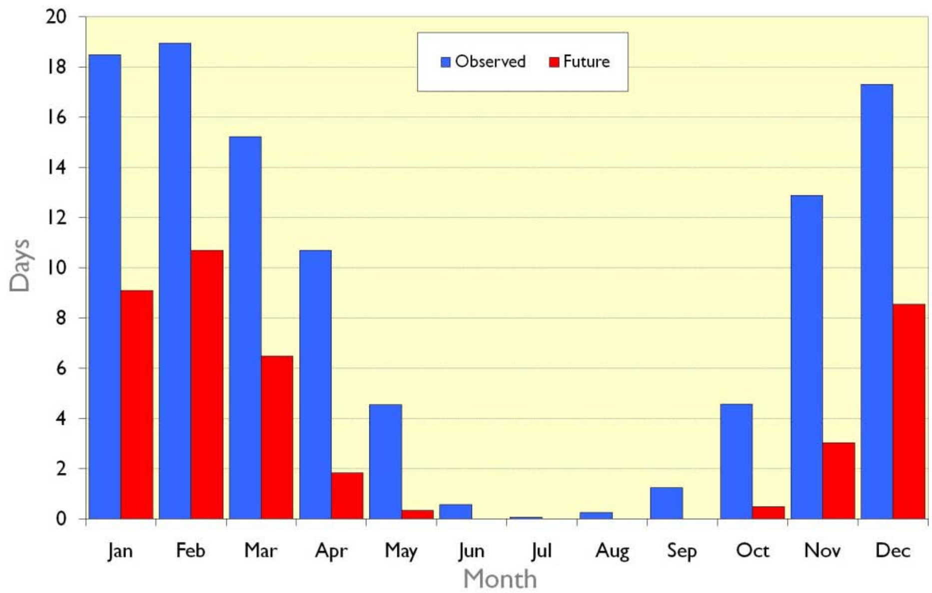

Figure 8: Average Frost Days by Month

Field Access Period

Field capacity is defined as the amount of water that a soil can hold against gravity. Soil at field capacity is unable to bear cattle or machinery. This measure is affected by the texture and depth of the soil therefore we can customise these types of charts for specific soils. We define the *end of field capacity* as the first date at which the moisture in the soil drops 5mm below field capacity. Conversely, the *return to field capacity* is the date at which the soil refills back above this point (Figure 9).

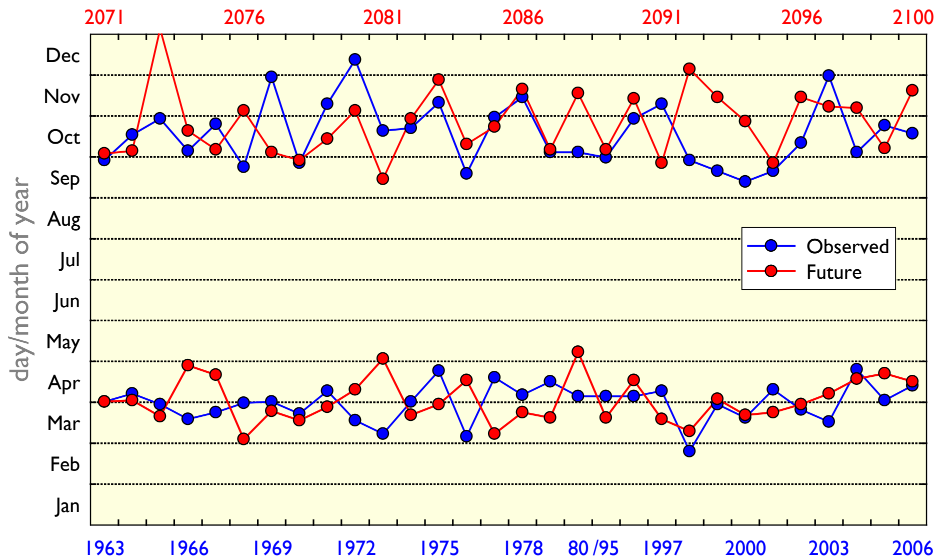

Figure 9: End and Return to Field Capacity

The end of field capacity in spring is expected to occur around 2 days later in the future and the return to field capacity is expected to occur 8 days later. Figure 10 shows the average number of days of field access by month. It shows a decrease in trafficability from April to June and an increase from July to December.

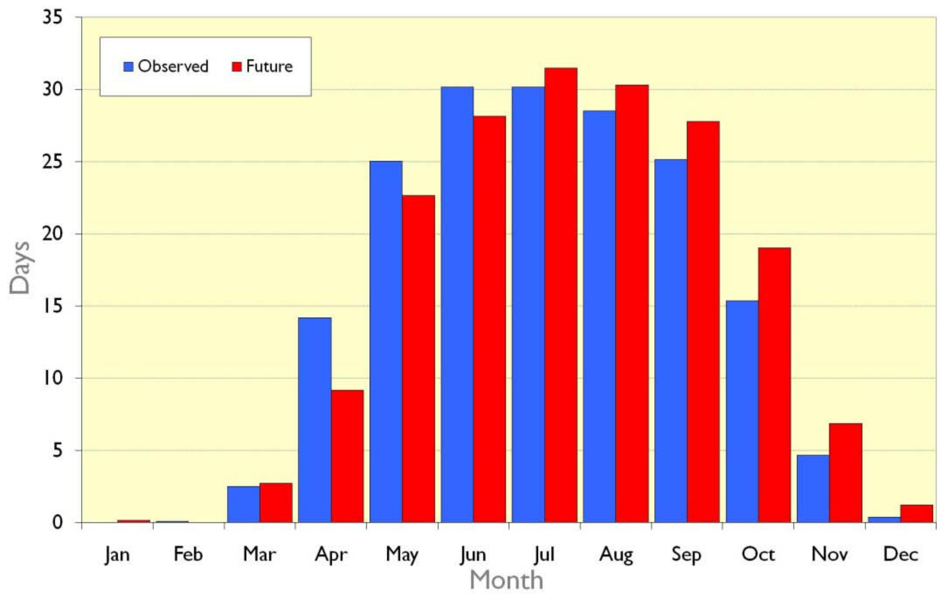

Figure 10: Days of Field Access by Month

Field Access during the Growing Season

An increased growing season is all very well but with the smaller increase in access period it might not be possible to carry out field operations during extended growing season. Figure 11 shows the average number of days per month that the temperature is above the growing base temperature and it is possible to access the field.

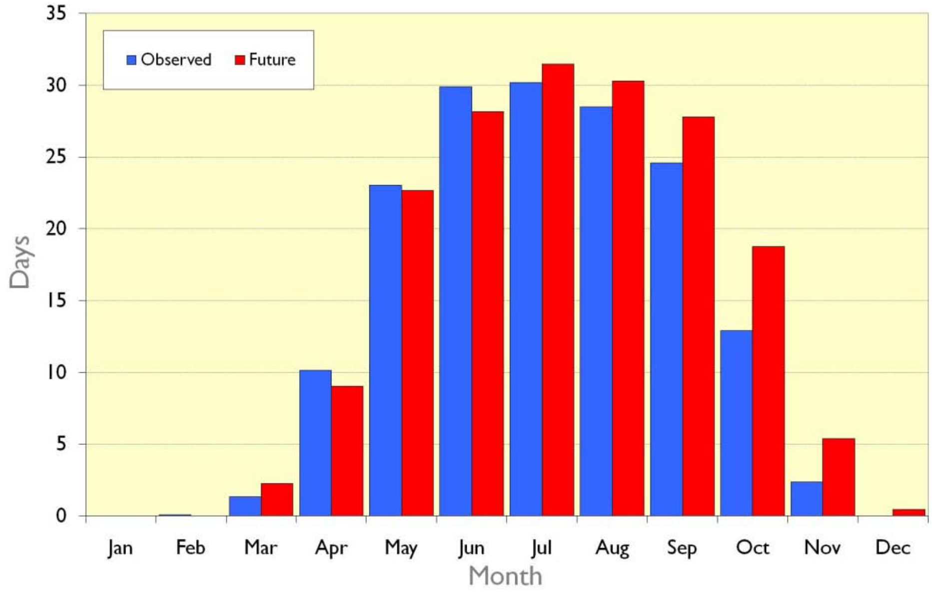

Figure 11: Average Number of Accessible & Growing Days by Month

This chart shows that the number of accessible and growing days will increase in late summer and autumn.

Soil Moisture

An understanding of the water in the soil will be more important than ever with a changing climate. If climate change brings bigger rain events then we could be faced with an increased risk of saturated soils and erosion. Increased temperatures could mean that the soil dries out more often. We can, therefore, expect the soil to be pushed harder in the years ahead. The examples in this section use a 50cm sandy silt loam soil profile. For Tarland '66, '98 and '02 were amongst the wettest on record while '72, '76 and '03 were amongst the driest. Figure 12 and Table 1 show a comparison of the driest years for the observed and future periods.

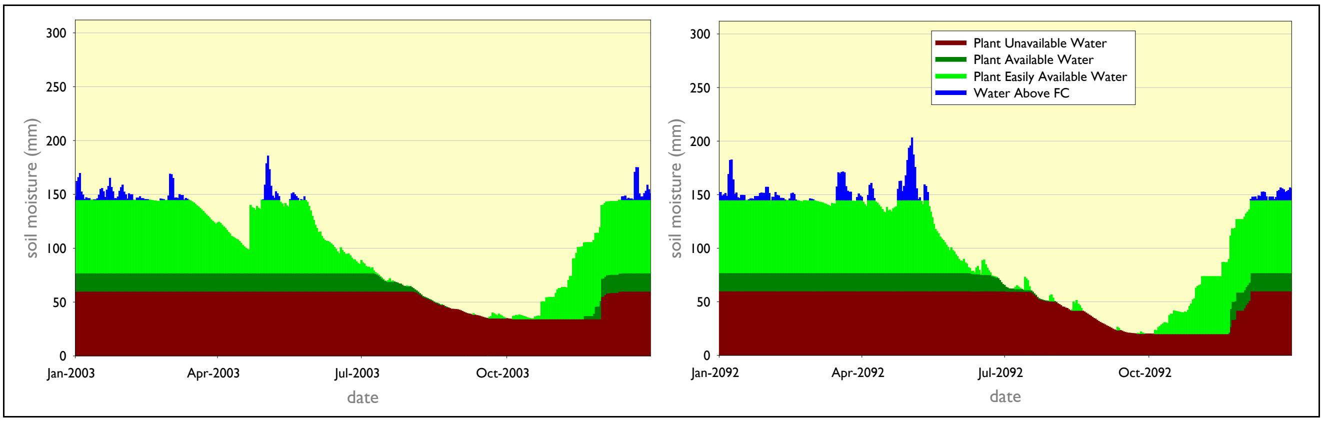

Figure 12: Dry year for the observed period (left) and future period (right)

The light green portion of the chart represents water which is easily available to crops. The dark green portion represents water that is available to crops but is difficult to extract and will impair growth. The dark red portion represents soil water that cannot be extracted by the crop. Blue is water above field capacity which is retained in the soil for a few days before draining or running off. We calculate the driest year as the year with the most days where water is unavailable to the plant (or where none of these days occur we would select the year with the most days where water is not easily available to the plant).

Table 1: Comparison of water availability for driest years in observed and future datasets

	Observed	Future
Days at Saturation Point	0	0
Days at or above Field Capacity	136	147
Days of Plant Easily Available Water	305	293
Days of Plant Available Water	337	324
Days of Plant Unavailable Water	28	42

Figure 13 and Table 2 show a comparison of the wettest years. We calculate the wettest year as the year which has the smallest SMD_{max} (i.e. the smallest peak soil moisture deficit) value.

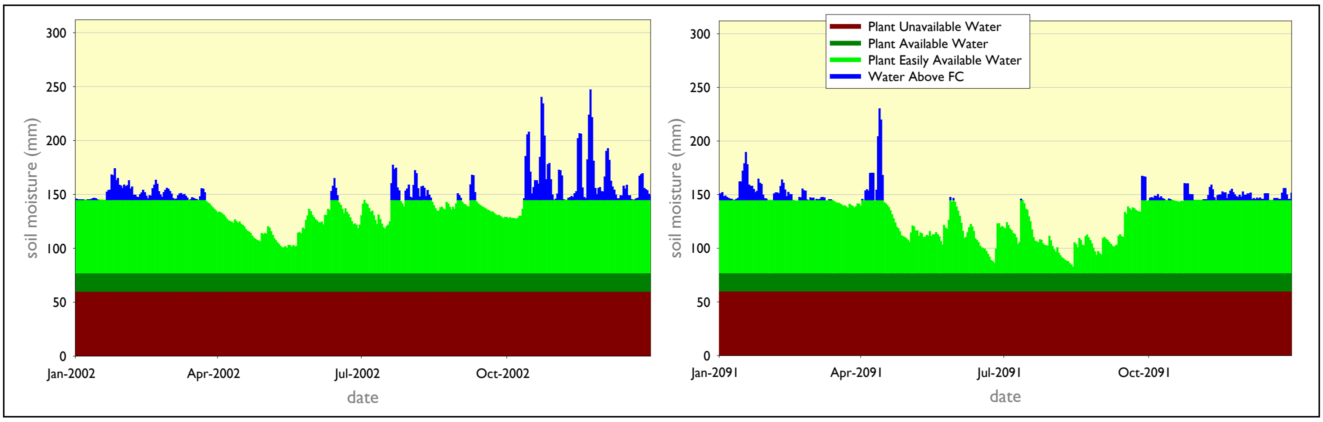

Figure 13: Wet year for the observed period (left) and future period (right)

Table 2: Comparison of water availability for wettest years in observed and future datasets

	Observed	Future
Days at Saturation Point	0	0
Days at or above Field Capacity	220	203
Days of Plant Easily Available Water	365	365
Days of Plant Available Water	365	365
Days of Plant Unavailable Water	0	0

Compared with the wettest year in the observed dataset, the wettest year in the future will have fewer days where water is at or above field capacity thus giving an increase in field access days.

Figure 14 shows a typical observed and future year. The typical year is calculated as the median dry year. i.e. The median year for the count of days where water is unavailable to the plant (or where none of these days occur we would select the median year for the count of days where water is not easily available to the plant).

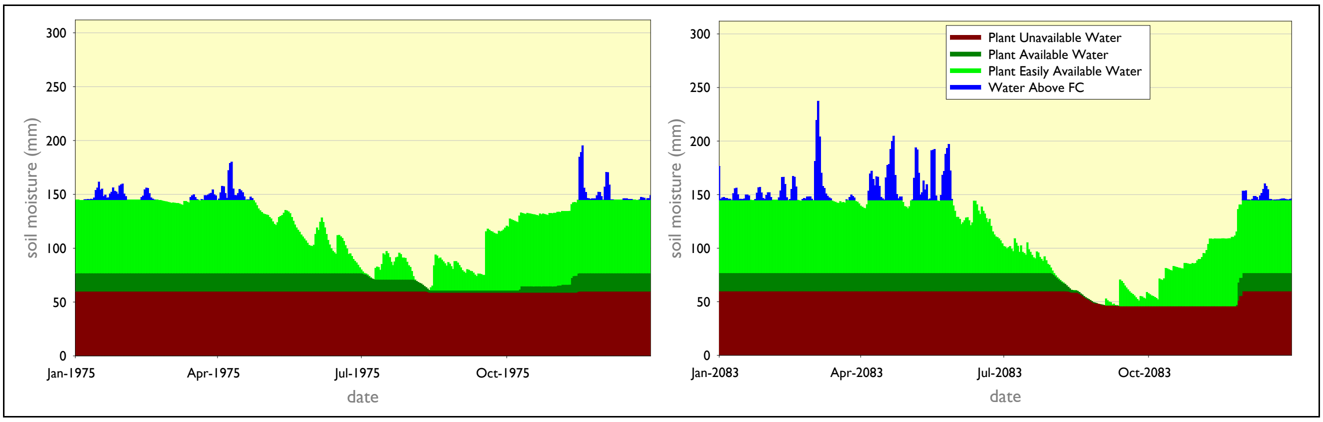

Figure 14: Typical year for the observed period (left) and future period (right)

Figure 15 shows that the average number of days per month where water is expected to be either unavailable or more difficult for the plant to extract from the soil is increasing between June and September.

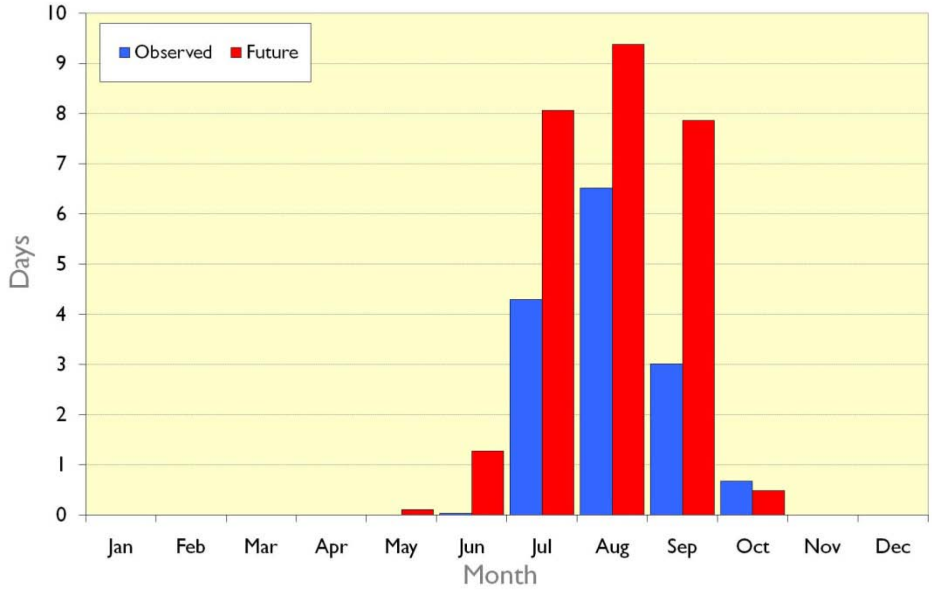

Figure 15: Average Days by Month where water is not easily available to plant

In order to gain an understanding of how a typical sequence of years would look we have shown the soil moisture profiles for 10-year periods in the observed and future datasets (Figure 16).

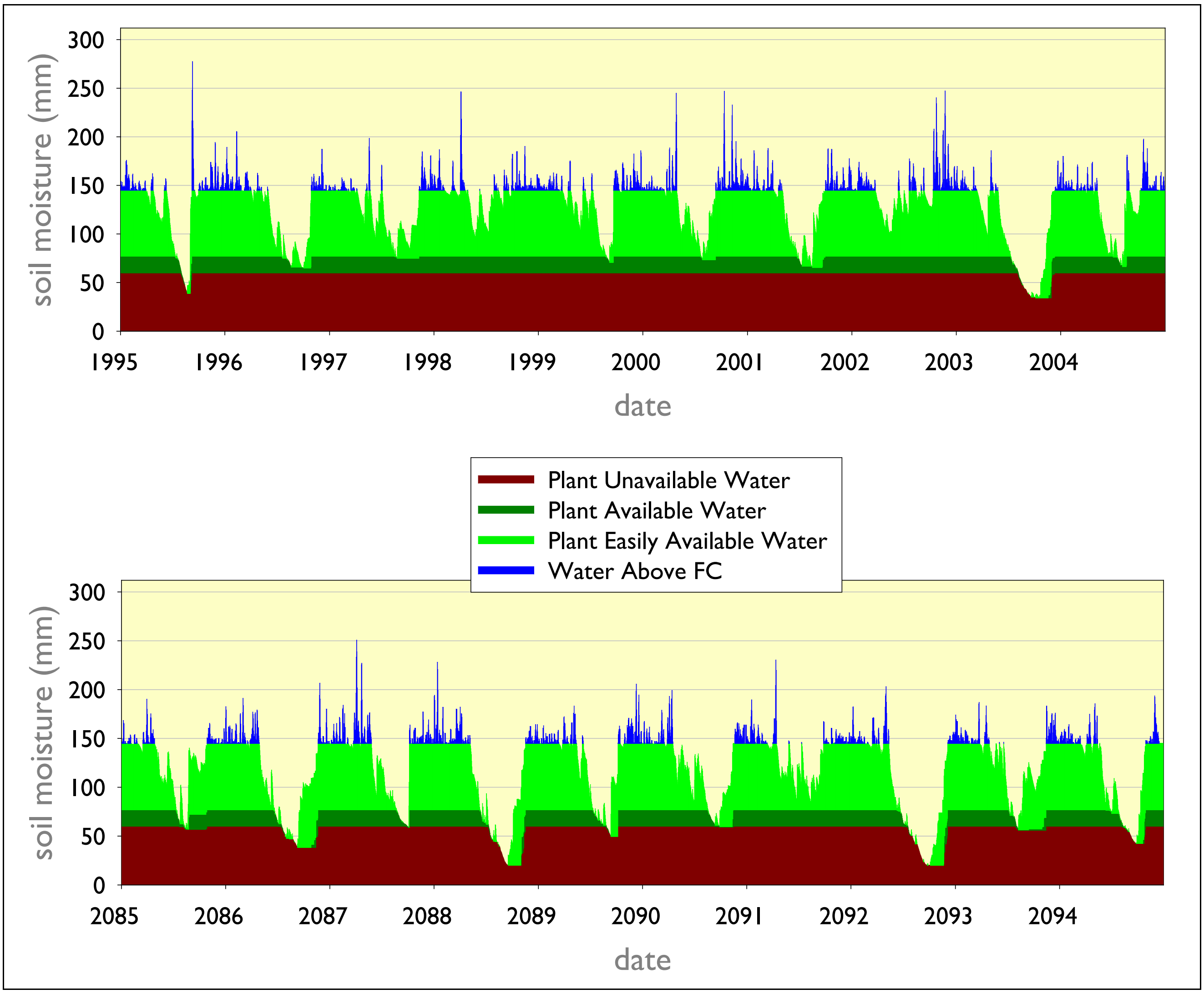

Figure 16: 10-year sample soil moisture profiles: observed (top) and future (bottom)

Summary of Agro-meteorological Indicators

Table 3 and Table 4 give a summary of how the Tarland indicators compare to a selection of other Scottish sites. Blue arrows to the left denote less or earlier while orange arrows to the right denote more or later.

Table 3: Indicators showing the average change between observed and future datasets (part 1)

Indicator	Aberdeen	Mylnefield	Carnwath	Galashiels	Eskd'muir	**Tarland***
Soil Depth (cm) & Type	50 SZL	50 SZL	50 L	50 CL	50 L	**50 SZL**
Observed Period	1961-1990	1961-1990	1970-2000	1967-1997	1970-2000	**1963-80 1995-06**
Average Daily Temp. (^{o}C)	➤ 2.8	➤ 3.1	➤ 2.8	➤ 3.0	➤ 3.0	**➤ 3.0**
Average Annual Rainfall (mm)	➤ 36	➤ 26	➤ 35	◄ 16	➤ 20	**➤ 127**
Start of the Growing Season (day)	◄ 48	◄ 35	◄ 37	◄ 36	◄ 50	**◄ 45**
Tsum200 (day)	◄ 22	◄ 22	◄ 21	◄ 25	◄ 26	**◄ 27**
End of Field Capacity (day)	◄ 3	◄ 2	n/a	◄ 4	◄ 7	**➤ 2**
Last Air Frost in Spring (day)	◄ 42	◄ 41	◄ 52	◄ 32	◄ 49	**◄ 45**
Return to Field Capacity (day)	➤ 14	➤ 18	n/a	➤ 26	➤ 11	**➤ 8**
End of Growing Season (day)	➤ 17	➤ 17	➤ 16	➤ 20	➤ 23	**➤ 22**
Dry Soil (days)	➤ 3	➤ 11	n/a	➤ 12	➤ 1	**➤ 7**
Growing Season Length (days)	➤ 64	➤ 63	➤ 58	➤ 62	➤ 66	**➤ 63**
Access Period Length (days)	➤ 11	➤ 19	n/a	➤ 36	➤ 22	**➤ 9**
Access during Growing Season (days)	➤ 20	➤ 26	n/a	➤ 42	➤ 30	**➤ 18**

Table 4:Indicators showing the average change between observed and future datasets (part 2)

Indicator	Dumfries	Auc'cruive	Prabost	Lairg	Dunst'age	**Tarland***
Soil Depth (cm) & Type	50 CL	50 L	40 SL	40 SL	40 SL	**50 SZL**
Observed Period	1961-1990	1970-2000	1960-1990	1971-1998	1971-1994	**1963-80 1995-06**
Average Daily Temp. (^{o}C)	➤ 3.3	➤ 2.8	➤ 1.2	➤ 2.6	➤ 2.9	**➤ 3.0**
Average Annual Rainfall (mm)	➤ 100	➤ 70	➤ 310	➤ 36	➤ 209	**➤ 127**
Start of the Growing Season (day)	◄ 27	◄ 14	◄ 30	◄ 39	◄ 30	**◄ 45**
Tsum200 (day)	◄ 22	◄ 16	◄ 16	◄ 21	◄ 15	**◄ 27**
End of Field Capacity (day)	➤ 2	◄ 3	◄ 6	◄ 6	◄ 5	**➤ 2**
Last Air Frost in Spring (day)	◄ 36	◄ 37	◄ 63	◄ 47	◄ 35	**◄ 45**
Return to Field Capacity (day)	➤ 23	➤ 18	➤ 10	➤ 9	➤ 12	**➤ 8**
End of Growing Season (day)	➤ 19	➤ 20	➤ 16	➤ 17	➤ 11	**➤ 22**
Dry Soil (days)	➤ 13	0	0	◄ 1	➤ 2	**➤ 7**
Growing Season Length (days)	➤ 60	➤ 55	➤ 58	➤ 59	➤ 51	**➤ 63**
Access Period Length (days)	➤ 47	➤ 30	➤ 3	◄ 7	➤ 9	**➤ 9**
Access during Growing Season (days)	➤ 51	➤ 33	➤ 3	◄ 2	➤ 10	**➤ 18**