**THESE NOTES REFER THE FOLLOWING ATTACHED FILES**

*EDEN CROP CYCLES.xlsx*

This file details each crop’s production cycle and management in the Eden catchment. It also includes a worksheet with the crop cycles of those crops that receive organic fertilisers.

*EDEN ROTATIONS.xlsx*

This file details the main catchment crop rotations for the EDEN, including variants of the main crop rotations with cover crops.

*WENSUM CROP CYCLES.xlsx*

This file details each crop’s production cycle and management in the Wensum catchment. It also includes a worksheet with the crop cycles of those crops that receive organic fertiliser.

*WENSUM ROTATIONS.xlsx*

This file details the main catchment crop rotations for the WENSUM, including variants of the main crop rotations with cover crops.

*SOIL PROPERTIES 1.xlsx*

The soil properties of the EDEN and WENSUM catchment

*EPIC OUTPUT BASICS.xlsx*

Outlines way to make the most of the weather data and incremental fertiliser use.

*\*\*\*ALL OF THE FOLLOWING IS IN REFERENCE TO THE* ***EDEN*** *FILES FOR ILLUSTRATION. THE EXACT SAME APPLIES TO THE WENSUM CATCHMENT. THE WENSUM’S PREDOMINANTLY ARABLE MODELLING IS A LOT SIMPLER THAN THE EDEN’S PREDOMINANTLY LIVESTOCK MODELLING.*

***1) WEATHER DATA***

The weather data (temperature and precipitation) is in a dropbox folder at:
[https://www.dropbox.com/sh/v6c669efcnx5og4/D8WDVJbJXe](https://mail.udbs.dur.ac.uk/owa/redir.aspx?C=MnZWNqzMb0OL0vVw1_DsjRmqWIeWCNAIaW639C5HBeIeOVmUTgIcc4XCQWOFqPrsc40qpHS7Nak.&URL=https%3a%2f%2fwww.dropbox.com%2fsh%2fv6c669efcnx5og4%2fD8WDVJbJXe" \t "_blank)

ACTUAL DATA: The two excel data sets are actual historic 58 years of continuous weather data for both catchments. As per your email, you will be able to estimate PET and mean solar radiation using the Hargreaves method etc.

CLIMATE CHANGE DATA: The weather data also includes 3 climate change scenarios from a weather generator for each catchment. Please see section 12, OUTSTANDING SCENARIOS, for details.

MAKING THE MOST OF 58 YEARS WEATHER: As we only have 58 years of continuous historic weather data, and in order to make the most of it, we propose running EPIC in such a way that each crop in a rotation is simulated for each of the 58 years. You could do this by starting each crop rotation from a different weather year.

This is illustrated in WORKSHEET: “58 YEARS WEATHER” (*EPIC OUTPUT BASICS.xlsx*). Here, in *simulation 1*, WW (winter wheat) is simulated in weather year 1,8, 15,29… or every following 7th year's weather. In order to simulate WW’s response under all 58 years of weather, in *simulation 2* ww is exposed to year 2’s weather, and *simulation 3*’s from the weather data’s 3rd year etc. This way WW can simulated for all 58 years of weather data.

***2) CROP CYCLES****. EDEN CROP CYCLES.XLSX*

This file details the management of each crop and the approximate dates of the main activities.

*DATES*

The dates of activities are narrowed down to the month. This is reasonable as weather variability means that most farmers cannot target particular days and instead have a chosen month in mind. Feel free to use any specific daily date in the specified month. Sometimes we have been more accurate with the inclusion of *early* or *late* before a month. Approximate dates may also give you flexibility in sequencing activities between crops in EPIC.

*ARTIFICAL FERTILISER RATIOS*

The amount and timing of each fertilising input (NPK) is stated as a ***ratio***of the ***total amount of N, P and K*** *to the applied to the crop* (*CROP MAX ARTIFICIAL FERTILISER LEVEL*).E.g. consider the first EDEN crop WW (winter wheat). The base fertiliser is applied in Oct but this only comprises of a P and K application. N is NOT applied in Oct. In fact the total amount of P and K that the crop receives is applied in Oct – this is shown by the “1”. However in March 0.33 of the total N applied to the crop is applied. At this time no P and K is applied. Similarly another 0.33 is applied in April and another 0.33 in may (totalling 1).

*“GRASS” RESEED*

*“Reseed” after a particular grass type* (GRAZE GRASS 2 RESEED or SIL 4 RESEED etc.) outlines how to establish a particular grass type (GRAZE 2, SIL 4 ETC.). After September ploughing, cultivation and sowing of the grass type switch to management of whatever the reseed is destined to become, e.g. SIL LFA RESEED means that the sown grass is destined to become "SIL LFA", thus after the RESEED follow management of cell ***J59*** onwards (*EDEN CROP CYCLES.xlsx*). If destinated to become "GRAZE 2" then after Sep follow the management as outlined in cell ***B122*** onwards; likewise, if "SIL 4" then follow ***N89*** onwards.

*GRASS KILL*

Similarly, after a couple of years of a grass crop type it maybe terminated or killed (e.g. SIL 3 KILL, GRAZE 2 KILL, or HAY 2 KILL). This means that the particular grass crop will be terminated by DESSICATION in SEPTEMBER. The management of the grassland is entirely the same as before, besides the dessication.

***3****)* ***MAIN CROP ROTATIONS.*** *EDEN ROTATIONS.xlsx*

The ***main crop rotations*** are numbered 1-24, whereas the *long-term* *continuous* crops (sometimes with a minor rotation component) are numbered 25-37. These are mainly long-term permanent grasslands. Please note a few exceptions such as *miscanthus* (rotation 25) that is grown continuously for 20 years and followed by cereals for 3 years before returning to 20 years of miscanthus again.

***4) COVER CROPS SCENARIOS.*** *EDEN ROTATIONS.xlsx*

We would like to simulate the effect of including 4 different cover/catch crops: stubble turnips, winter rye, forage rape and mustard in the EDEN and Phacelia, winter rye, forage rape and mustard in the WENSUM catchment.

Cover crops without FYM/SLURRY and those with FYM/SLURRY are in separate worksheets and are named accordingly.

Crop rotations 38-61 (**sturnip (cc)**), 62-85 (**wrye (cc)**), 86-109 (**frappe (cc)**), and 110-113 (**must (cc)**) are really just the main crop rotations 1-24 but with stubble turnips, winter rye, forage rape and mustard respectively as cover crops in between spring crops. Please note that the inclusion of these cover crops in the rotations sometimes changes the ploughing date and fertiliser application dates of next subsequent crop (i.e. the crop following the cover crop). The altered subsequent crop in the rotation has a ‘**B’** after them. There are *only 3 such crops in the EDEN: SBAR B, SOATS B and SBEANS B*. Comparing SBAR with SBAR B in spreadsheet ‘EDEN CROP CYCLES’ will show that SBAR B is ploughed in Feb as opposed to Nov due to the inclusion of the preceding cover crop over winter – otherwise they are mostly identical (they might not be identical - especially in the WENSUM, where there are 8 “B” crops: sbar B, onions B, vpeas B, pot B, sbeans B, maize B, sbeet B and carrots B). For example consider ***main crop rotation*** number *5*:

SBAR, SOATS, HAY 2 RESEED, HAY 2, HAY 2, HAY 2 KILL…. back to SBAR, SOATS, HAY 2 RESEED, HAY 2,… ETC.

With the inclusion of stubble turnips (sturnip (cc)) as cover crop this rotation becomes *rotation 42*:

STURNIP (CC), SBAR B, STURNIP (CC), SOATS B, HAY 2 RESEED, HAY 2, HAY 2, HAY 2 KILL…BACK TO STURNIP (CC), SBAR B, STURNIP (CC), SOATS B, HAY 2 RESEED… ETC.

Likewise with the inclusion of winter rye (wrye (cc)) as cover crop this rotation becomes *rotation 66*:

WRYE (CC), SBAR B, WRYE (CC), SOATS B, HAY 2 RESEED, HAY 2, HAY 2, HAY 2 KILL…BACK TO WRYE (CC), SBAR B, WRYE (CC), SOATS B, HAY 2 RESEED… ETC.

Similarly with the inclusion of forage rape (frappe (cc)) as cover crop this rotation becomes *rotation 90*:

FRAPE (CC), SBAR B, FRAPE (CC), SOATS B, HAY 2 RESEED, HAY 2, HAY 2, HAY 2 KILL…BACK TO FRAPE (CC), SBAR B, FRAPE (CC), SOATS B, HAY 2 RESEED… ETC.

And lastly with the inclusion of mustard (must (cc)) as cover crop this rotation becomes *rotation 114*:

MUST (CC), SBAR B, MUST (CC), SOATS B, HAY 2 RESEED, HAY 2, HAY 2, HAY 2 KILL…BACK TO MUST (CC), SBAR B, MUST (CC), SOATS B, HAY 2 RESEED… ETC.

Therefore rotation 5 is the main rotation, but it exists in 4 other forms with different cover crops as rotations 42, 66, 90 and 114.

***NOTE: FOR BOTH THE EDEN AND WENSUM, WHEN PLANTING A COVER CROP AFTER POTATOES OR MAIZE (BOTH HARVESTED IN EARLY OCT), THE COVER CROP’S CULTIVATION AND DRILL DATES ARE IN EARLY OCT RIGHT AFTER THE POTATO AND MAIZE HARVEST.***

*IMPORTANT CATCHMENT DIFFERENCE: Cover crops (excluding mustard) in the Eden will be mostly foraged/grazed by livestock and what is left of them is dessicated and ploughed under in preparation for the following crop. Whereas in the Wensum there is very little livestock so the bulk of the cover crops will be mostly ploughed under after dessication at the end of their life cycle in preparation for the following crop.*

***5) CONSERVATION TILLAGE SCENARIOS.*** *EDEN CROP CYCLES.XLSX*

The current tillage practice used on each crop is labelled as “conventional”. In addition to modelling the existing conventional tillage practice, we are interested in the effect of using 3 types of CONSERVATION TILLAGE (non inversion min-till, strip till and no- till regime) for *SOME* crops in the Eden and *MOST* crops in the WENSUM. By this we mean:

*MIN-TILL:* Cultivation to create stale seedbed; spray off weeds; shallow tine or disc.

*STRIP-TILL:* Cultivation to create strips. Drill into strips. Post emergence spray as needed.

*NO-TILL:* Spray off weeds in stubble. *Direct drill* into the undisturbed surface. Post emergence spray as needed.

If a crop can be tilled using conservation tillage then it is indicated in the spread sheet by the presence of “min-till; strip till; no till” under *tillage scenario*. Please note that cover/catch crops are normally min-till anyway (no ploughing), so the conservation tillage scenarios here are restricted to only “strip till and no till”.

When modelling the non-inversion conservation tillage scenarios every other management crop cycle action remains the same except the tillage. So in modelling the MIN-TILL scenario, every crop in a rotation is tilled using min-till – provided it can be. If a crop can be min tilled then the crop’s crop cycle will indicate it (e.g. sugar beet, onion, carrots and miscanthus only be tilled conventionally, so these crops will always be conventionally ploughed even though other crops in the rotation are min-tilled). Likewise in modelling the STRIP TILL scenario every crop is strip tilled except those that can’t be as indicated in their crop cycle. The same applies to NO-TILL.

*COMBINED COVER CROP AND CONSERVATION TILLAGE SCENARIOS*

In modelling the 3 conservation tillage scenarios (min-till; strip till; no till) *with* cover crops everything remains the same except that the cover crops are also tilled using min-till (the cover crop default), strip-till and no-till.

NOTE: There is no conservation tillage is used in growing Miscanthus (elephant grass) production, nor in the management of the three other crops that break Miscanthus’s 20 year rotation, i.e. wosr, ww and wbar.

***6) ORGANIC FERTILISER APPLICATIONS***

*WORKSHEET: “MANURE AND SLURRY CROPS”* *(EDEN CROP CYCLES.xlsx)* contains the crop cycles of a small subset of crops and grasses that receive organic fertilisers. The purpose is to estimate the effect of applying specific quantities of farm yard manure (FYM) and slurry with known N, P and K content to some organic fertiliser tolerant crops in *addition* to inorganic fertiliser top ups. So farmers apply fixed quantities of FYM (high lighted dark red) and slurry (high lighted orange) to these crops and then make up the remaining fertiliser requirement by toping up with inorganic fertiliser in fixed ratios (high lighted yellow) – as described above in FERTILISER RATIOS section. The *CROP MAX ARTIFICIAL FERTILISER LEVEL* is the total artificial fertiliser application level *in addition* to the organic manure.

You can make the following assumptions about the applied manure and slurry:

FYM assumptions: 25% dry matter; total nutrients N=6kg/t, P=3.2kg/t, K=8kg/t. Of this total, we have *assumed for guidance only*, that approximately 10% of the N is available to the following crop and 100% of the P and K is available to future crops.

SLURRY ASSUMPTIONS: 6% dry matter; total nutrients N=2.6kg/m3, P=1.2kg/m3, K=3.2kg/m3. Of this total, *we have assumed for guidance only*, that approximately 35% of the N is available to the following crop and 100% of the P and K is available to future crops.

How much of the total nutrients in the FYM and SLURRY that are *actually* available to the following crop(s) will be better approximated by EPIC, as it will take the weather, soil and management parameters into account. I have just used rough estimates in the spread sheet (cell C6, D6, E6, etc.) for guidance to determine the amount of *CROP MAX ARTIFICIAL FERTILISER LEVEL.*

*NOTE:*

1) All manure and slurry is surface spread (not injected).

2) If a farmer applies manure or slurry then he must plough afterwards – thus non-inversion conservation tillage is not an option when organic fertilisers are applied.

3) In modelling crops receiving organic fertilisers *in the presence of cover crops*, there should not be a sequencing problem are all manures/slurries are applied to arable SPRING crops in early Feb after the previous cover crop has been dessicated.

***7) IRRIGATION***

There is NO irrigation in the EDEN. However, potatoes, carrots, onions and to a lesser extent sugar beet are irrigated in the Wensum. Farmers use mobile rain gun irrigators or boom irrigators.

*CARROTS AND ONIONS*: You can assume that carrot and onion irrigation is optimised to maximise yield 90% of the time.

*POTATOES:* Normally farmers follow Table 1’s irrigation-scheduling rule for potatoes:

Table 1.

|  |  |  |
| --- | --- | --- |
|  | 20% crop cover to 4-5 weeks after tuber initiation | 4-5 weeks after tuber initiation to late harvest |
| Typical irrigation schedule for Potatoes | 20 mm @ 25 mm SMD | 25 mm @ 35 mm SMD |

SMD: soil moisture deficit.

SUGAR BEET:

Irrigation should be applied whenever the current SMD is likely to exceed a value at which water stress adversely affects growth. This value, the **limiting deficit** (Table 2 below), is larger in moisture-retentive soils and increases in successive months as rooting becomes deeper and potential evaporation decreases. If the soil type or date fall between the entries in Table 2, intermediate values of the limiting deficit can be used. You can use this as a guide to how farmer would irrigate.

Table 2. **Limiting soil moisture deficits** (mm) for sugar beet

|  |  |  |  |
| --- | --- | --- | --- |
| **Coarse sand** | **Loamy sand** | **Sandy loam** | **Clay loam** |
| **mid-June** | 25 | 30 | 35 |  |
| **mid-July** | 35 | 40 | 50 |  |
| **mid-Aug** | 50 | 60 | 75 |  |
| **mid-Sept** | 65 | 75 | 125 |  |

Irrigation amount: The depth of water per application is usually about 25mm. Farmers are advised to leave a SMD of at least 10mm after irrigation.

***8) LIVESTOCK MANAGEMENT***

1. Graze 1 (WENSUM), GRAZE 2, GRAZE 3, GRAZE 4 and GRAZE 6 is only grazed with livestock from mid APRIL to mid OCT (6 months). Between mid OCT to mid APRIL livestock is housed indoors. So there is no manure or slurry deposition on GRAZE 2, GRAZE 3, GRAZE 4 and GRAZE 6 between mid OCT to mid APRIL.
2. “GRAZE LFA” (rotation 3), “LFA PERM. GRAZE” (rotation 27) and “PERM. GRAZE GRASS 2 N APPLICATIONS” (rotation 28) have grazing sheep on the land all year around.

***9) GENERAL CROP MANAGEMENT***

1. All land is sub-soiled every 8 years with the *exception* of rough grazing, miscanthus and permanent grassland (anything with “PERM.” in the name). The sub-soiling normally happens during the arable part of a rotation.
2. All land is limed every 8 years in the Eden and every 6 years in the Wensum.
3. In both catchments permanent grasslands are “slot seeded” (using a slot seeding machine) with extra grass seeds to improve existing established grassland every 4 years.
4. All catchment land in both catchments is either tile or stone drained.
5. In the WENSUM nitrogen usage is generally about two-thirds in the form of ammonium nitrate and one-third urea.
6. In the EDEN grassland receives ammonium nitrate, whereas arable crops are fertilised with urea or ammonium nitrate. So ammonium nitrate is the most common type of fertiliser.

***10) MODELLING SCENARIOS***

WORKSHEET: “*FERTILISER INPUT LEVELS” in EPIC OUTPUT BASICS.XLSX*

We are essentially interested in modelling the crop yield and environmental impact (diffuse nutrient, sediment, carbon, gaseous etc.) of each nutrient (NPK) input’s increasing fertiliser use.

The maximum amount of N, P and K (different for each nutrient) is found in file *EDEN CROP CYLES.xlsx* in the row labelled *CROP MAX ARTIFICAL FERTLISER LEVEL*. Obviously, in the situations where FYM and/or Slurry is also applied we are interested in total pollution from the organic manures and artificial fertilisers for a given crop management.

Thus, model the following 8 farming scenarios:

*1) ARTIFICIAL FERTILISER (CONVENTIONAL)*

Main crops (artificial fertiliser only)

*2) ORGANIC FERTILISER*

Main crops + FYM/slurry (to the organic fertiliser “tolerant” crops)

*3) ARTIFICIAL FERTILISER (CONVENTIONAL) + COVER CROPS*

Main crops (artificial fertiliser only) + cover crops (stubble(cc)) (in WENSUM stubble turnips are replaced by PHYCELIA)

Main crops (artificial fertiliser only) + cover crops (wrye(cc))

Main crops (artificial fertiliser only) + cover crops (frape(cc))

Main crops (artificial fertiliser only) + cover crops (must(cc))

*4) ORGANIC FERTILISER + COVER CROPS*

Main crops + FYM/slurry + cover crops (stubble(cc)) (in WENSUM stubble turnips are replaced by PHYCELIA)

Main crops + FYM/slurry + cover crops (wrye(cc))

Main crops + FYM/slurry + cover crops (frape(cc))

Main crops + FYM/slurry + cover crops (must(cc))

*5) ARTIFICIAL FERTILISER (CONVENTIONAL) + CONSERVATION TILLAGE (MIN-TILL)*

Main crops (artificial fertiliser only) + conservation tillage (min-till)

6) *ARTIFICIAL FERTILISER (CONVENTIONAL) + CONSERVATION TILLAGE (NO-TILL)*

Main crops (artificial fertiliser only) + conservation tillage (no-till)

*7) CONSERVATION TILLAGE (MIN-TILL) + COVER CROPS*

*- MIN-TILL*

Main crops (artificial fertiliser only) + conservation tillage *(min-til)* + cover crops (stubble(cc))

Main crops (artificial fertiliser only) + conservation tillage *(min-til)* + cover crops (wrye(cc))

Main crops (artificial fertiliser only) + conservation tillage *(min-til)* + cover crops (frape(cc))

Main crops (artificial fertiliser only) + conservation tillage *(min-til)* + cover crops (must(cc))

*8) CONSERVATION TILLAGE (NO-TILL) + COVER CROPS*

 *- NO-TILL*

Main crops (artificial fertiliser only) + conservation tillage *(no-til)* + cover crops (stubble(cc))

Main crops (artificial fertiliser only) + conservation tillage *(no-til)* + cover crops (wrye(cc))

Main crops (artificial fertiliser only) + conservation tillage *(no-til)* + cover crops (frape(cc))

Main crops (artificial fertiliser only) + conservation tillage *(no-til)* + cover crops (must(cc))

**NOTE: THE STRIP TILL SCENARIOS WERE NOT MODELLED TO REDUCE THE VOLUME OF THE DATA OUTPUT, WHICH ALREADY EXCEEDS 90TB.**