Section 4

Adding Vegetation Carbon to the RothC Soil Carbon Model

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4. Adding Vegetation Carbon to the RothC Soil Carbon Model

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4.1. Introduction

Brown *et al.* (2003) described preliminary work to integrate two carbon cycle models for improved estimation of soil carbon for grasslands and other vegetation types. The models are BIOTA, a vegetation/soil C cycle model developed at CEH (Centre for Ecology and Hydrology), and RothC, a soil C cycle model developed at Rothamsted and widely applied in different environments. The work envisaged further application of linked models to predict C dynamics under a wide selection of land use types and management practices in the UK. In particular the advantage of using a model with modules describing the plant parts as well as the soil was of interest. These studies showed that with suitable parameter settings the plant carbon modules of Biota were able to generate litter inputs equivalent to those used as inputs to RothC. Hence where climate changes effects on soil carbon are of interest the linked effect of the effect of climate on the plant and litter components would be incorporated.

It was decided that as RothC is well established that additional code should be added, based on Biota, to model changes in plant and litter carbon

This report details the continuing work to integrate the CEH Biota plant carbon cycle model with the RothC v26.3 soil carbon cycle model.

4.2. Resume of approach to integration

RothC works on a monthly time-step basis, and obtains plant litter and climate datasets from external text files to drive these time-steps. It outputs a set of time-series soil carbon pool data upon completion.

Biota works on a daily time-step basis, and uses a set of plant parameter files, in conjunction with climate datasets, to drive a plant-growth model and outputs a set of time-series plant pool data upon completion.

The chosen point of interface between the two models is where RothC reads in its plant and climate datasets. The plant litter data is generated by Biota and fed into RothC, and the climate datasets are harmonised so that both models are running with identical data.

Figure 4-1 illustrates the input and output flows of the RothC, Biota and integrated models:

The integrated model has been constructed in such a way that that it retains the full capabilities to run the RothC model in its original form with all input being provided from simple text files. This is the default mode of operation of the model and the use of the Biota plant module to supply the litter must be explicitly requested.
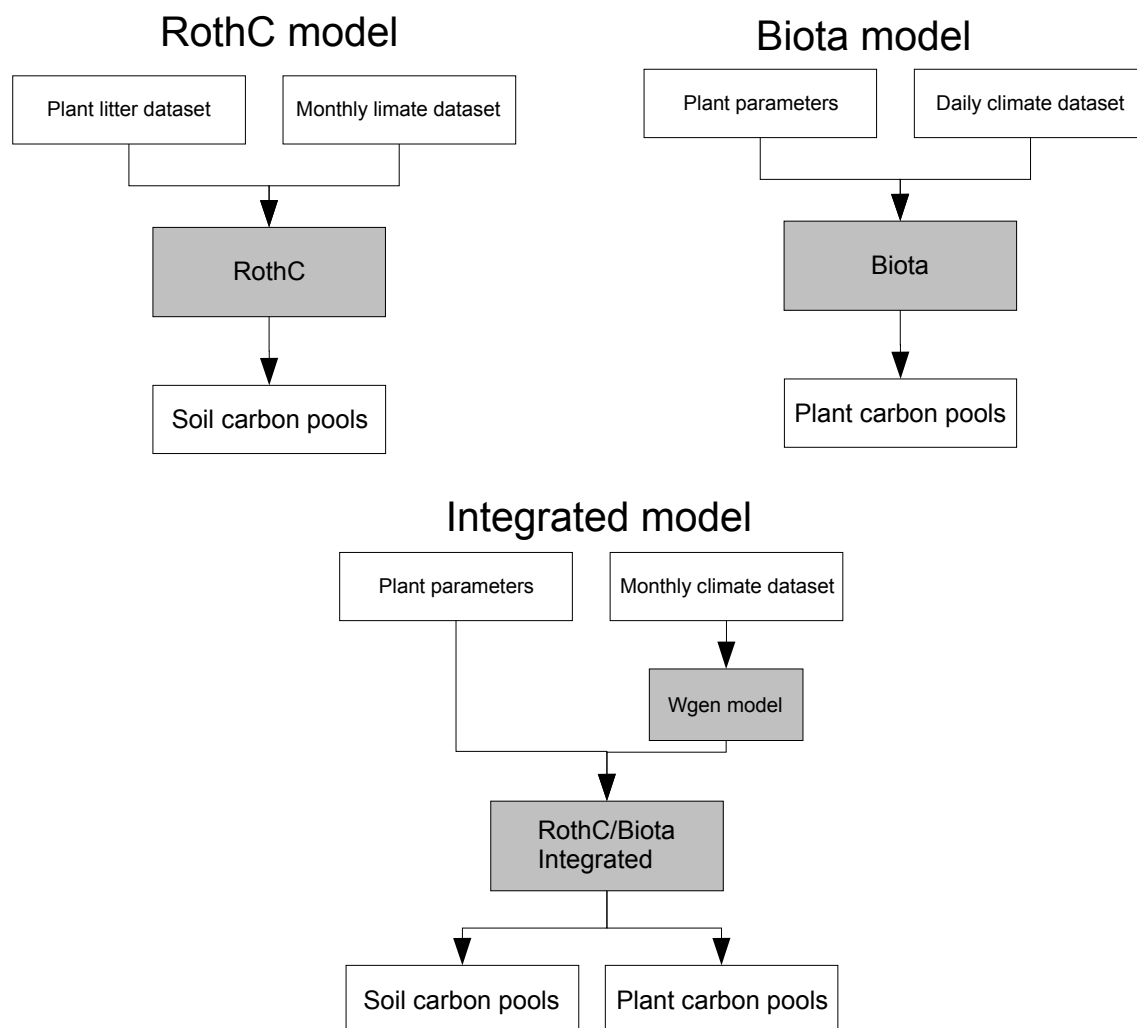
RothC model

Biota model

Integrated model

Figure 4-1 The input and output flows of the RothC, Biota and integrated models:

4.3. Plant module details

The plant (based on Biota) module has now been developed in order to allow a wide range of plant types to be implemented. Each type requires parameters setting the fraction of standing biomass that is transferred into the litter and hence soil organic matter pools. The types of plant can be broadly categorised into two:

- *Unmanaged*
  These are plant types that will generate litter at rates based on natural lifetimes and death rates. These parameters are now provided in parameter files as the fractions of above and below ground biomass in each month that become litter

- *Managed*
  These are plant types that will generate litter at rates based, as well as on natural death rates, on material dying at mowing or harvest events. These parameters are now provided in parameter files as the fractions of above and below ground biomass in each month, at mowing events and at harvest. For each of the events and at harvest some plant material will also be lost completely from the system as cuttings or products.

4.3.1. Plant types

4.3.1.(a) Grass

Grass can be both managed, and unmanaged.

Unmanaged grass
Requires 12 natural loss fractions (one per month). This loss is passed into the RothC soil module as litter.

Managed grass
Requires similar natural loss fractions as unmanaged grass but also up to three mowing dates and parameters indicating for each event:

   a) fraction of "biomass" removed from the system by mowing

   b) fraction of "biomass" remaining as detritus (i.e. to be input to soil module as litter)

4.3.1.(b) Crops

Crops are always managed, and are divided into two sub-types, cereal and root. Both require the following parameters:

   a) planting date

   b) harvesting date

Both sub-types require natural biomass loss per month as for grass. This loss is passed to the soil module as litter.

For cereal sub-types, the fraction of biomass that is roots at harvest time which is also passed to the soil module as litter. For root crop sub-types the root fraction of biomass is of course removed from the system.

4.3.1.(c) Coniferous trees

Can be managed, or unmanaged. Code not yet fully developed.

Unmanaged coniferous trees

Requires 12 natural loss fractions (one per month). This loss is passed into the RothC soil module as litter

Managed coniferous trees

Requires the same natural loss fractions as unmanaged coniferous trees, as well as:

   a) harvesting date (expressed in years since planting date)

   b) fraction of leaves passing to soil module as litter

   c) fraction of stems passing to soil module as litter

   d) fraction of roots passing to soil module as litter

4.3.1.(d) Broadleaf trees

Can be managed, or unmanaged. Code not yet fully developed.

Unmanaged broadleaf trees

Requires 12 natural loss fractions (one per month), tuned to budburst and leaf fall dates. This loss is passed into the RothC soil module as litter.

Managed broadleaf trees

Requires the same natural loss fractions tuned to budburst/leaf fall as unmanaged broadleaf trees, as well as:

a) harvesting date (expressed in years since planting date)

b) fraction of leaves passing to soil module as litter

c) fraction of stems passing to soil module as litter

d) fraction of roots passing to soil module as litter

4.4. Initial investigations of model output for unmanaged grass

One of the main concerns about the integration of the two models was that the plant additions figures generated by the Biota plant module would be a reasonable first-approximation match for the "real" input data as used by the standard RothC soil model.

To test this, a new structure of parameter file was designed and populated with appropriate parameters for unmanaged grass. The general structure of the proposed parameter files is given in Appendix I and examples for managed grass, unmanaged grass and crops in Appendix II.

For a typical set of parameter values for transfer of material from biomass to litter the new model compares well with the original RothC (standalone) both for the litter inputs and the estimated soil carbon at equilibrium (Table 4-1 and Figure 4-2). The RothC additions to the soil are however static, i.e. the same for each year, whereas the Biota generated values are modelled each year and will therefore track climate change or other imposed changes.

Table 4-1 Plant additions and estimated soil carbon from the Biota module and the original RothC measured data (t/ha) for unmanged grass. Pattern for Biota is determined by pattern of loss rate entered as monthly parameters but absolute values depend on modelled biomass stocks after 10,000 years to reach equilibrium

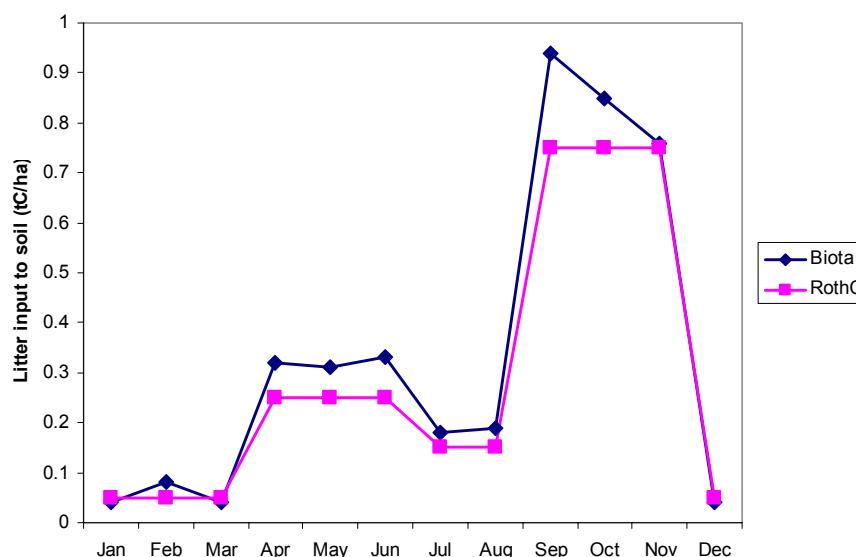| Month	Biota	RothC
Jan	0.04	0.05
Feb	0.08	0.05
Mar	0.04	0.05
Apr	0.32	0.25
May	0.31	0.25
Jun	0.33	0.25
Jul	0.18	0.15
Aug	0.19	0.15
Sep	0.94	0.75
Oct	0.85	0.75
Nov	0.76	0.75
Dec	0.04	0.05
Equilibrium soil carbon	30.1	34.5

Figure 4-2 Plant additions from the Biota module and the original RothC measured data

4.5. Data for preparation of biomass turn-over for different plant types

Several sources are available for information on litter production in grasses and crops (Sosanska et al. 2002). For crops parameters for the SUNDIAL model of nitrogen cycling captures much of the known data. From calculations of biomass in that model estimates of litter production per month can be made. This source is being used to develop litter production parameters for the Biota/RothC model for crop types. Four examples of litter production data are shown in Figure 4-3a-d. These are presented as fraction of the final (at harvest) biomass of the plant that is lost to the soil each month as litter for a range of final product yield. Work is in progress to estimate biomass growth through the season for typical crops using outputs from SUNDIAL to allow conversion of data such as that in Figure 4-3 to the fraction of standing biomass in a particular month that is lost as litter to soil.

4.6. Future work required before release of new version of RothC with integrated plant modules.

- Development of litter production parameters for crops using SUNDIAL output.

- Construction of full test parameter set for each vegetation type

- Comparison of outputs from old and new version of RothC with field data (SOMNET likely to be useful source)

4.7. References

G. Sozanska, P Smith, R. Milne, and T. A.W. Brown (2002) Linking Soil and Vegetation Carbon in Dynamic Models. In: *UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities.* Annual report for DEFRA Contract EPG1/1/160 (Ed. by R. Milne).

T. A.W. Brown, R. Milne, P Smith, and G. Sozanska (2003) Adding vegetation carbon to the RothC soil carbon model. In: UK Emissions by Sources and Removals by Sinks due to Land Use, Land Use Change and Forestry Activities. Annual report (2003) for DEFRA Contract EPG1/1/160 (Ed. by R. Milne).
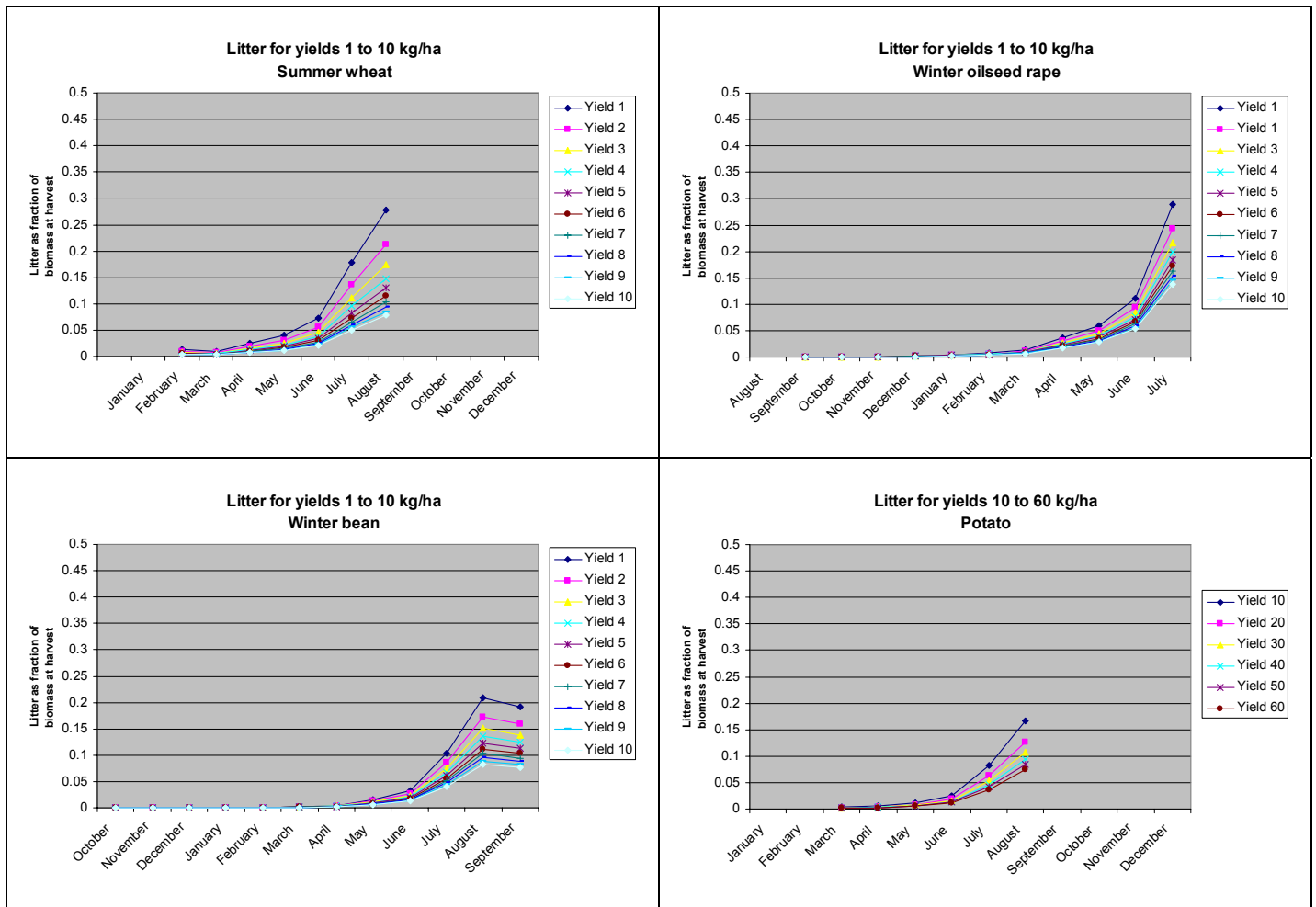
Figure 4-3 Litter production estimated from SUNDIAL nitrogen cycle model for: summer wheat, winter oilseed rape, winter beans and potato.

A.1. Appendix 1 Structure of plant parameter file

```
[Description]
Name=Grass

[Main]
MainAirTempThreshhold=<temperature>
rmParam1=<value>
rmParam2=<value>
rmParam3=<value>
NPPFactor=<value>

[Management]
Type=Managed|Unmanaged
 Additions=Grass|Crops|Trees
; For Type=Managed:
PlantingDay=<day>
HarvestingDay=<day>

; For all Types and Additions, a natural loss
;   fraction of biomass for each month
; For CROPS (have to be Managed)- fractions of biomass from Above (A) and Below
 ; (B) ground going to soil  in events, up to 3 if required for any reason
; A natural loss fraction of biomass for each month Above (A) and Below (B) ground
separately


NaturalLossA1=< fraction of biomass>
NaturalLossB1=< fraction of biomass>
….    .
….    .
NaturalLossA12=< fraction of biomass>
NaturalLossB12=< fraction of biomass>


; For GRASSES (can be Managed or Unmanaged)- fractions of biomass from Above (A) and
Below (B) ground going to soil
; Also  fraction of biomass Removed (R) at each event
; Maximum of 3 events (e.g cutting)
; Might be no events
EventDay1=<day>
EventLossA1=< fraction of biomass>   ; Transferred to soil
EventLossB1=< fraction of biomass>   ; Transferred to soil
EventLossR1=< fraction of biomass>   ; Removed

EventDay1=<day>
EventLossA2=< fraction of biomass>   ; Transferred to soil
EventLossB2=< fraction of biomass>   ; Transferred to soil
EventLossR2=< fraction of biomass>   ; Removed


EventDay3=<day>   ; Could be harvest
EventLossA3=< fraction of biomass>   ; Transferred to soil
EventLossB3=< fraction of biomass>   ; Transferred to soil
EventLossR3=< fraction of biomass>   ; Removed


; A natural loss fraction of biomass for each month Above (A) and Below (B) ground
separately
NaturalLossA1=< fraction of biomass>
NaturalLossB1=< fraction of biomass>
….    .
….    .
NaturalLossA12=< fraction of biomass>
NaturalLossB12=< fraction of biomass>
```

```
; For TREES (can be Managed or Unmanaged)- fractions of biomass from Above and Below
ground going to soil
; No decisions on other parameters yet.

 [assiml]
respdarkParam=<value>

[bioch]
d0=<value>
a1=<value>

[Biomass respiration]
Value=<value>

[Specific leaf area]
Value=<value>

[Beam extinction coefficent]
Value=<value>

[Diffuse extinction coefficent]
Value=<value>

[Maximum potential electron transport rate]
Value=<value>

[Temperature for photosynthesis]
Min=<value>
Opt=<value>
Max=<value>

[Carbon assimilate partitioning coefficent]
Leaf=<value>
Branch=<value>
Stem=<value>
Root=<value>

[Fraction of litter entering DPM]
Leaf=<value>
Branch=<value>
Stem=<value>
Root=<value>
```

A.2. Appendix IIa Example plant parameter file for type "unmanaged grass"

```
[Description]
Name=Unmanaged Grass Example

[Main]
MainAirTempThreshhold=-15
rmParam1=0.1
rmParam2=0.01
rmParam3=0.1
NPPFactor=0.8

[Management]
Type=Unmanaged
Additions=Grass

NaturalLossA1=0.01
NaturalLossB1=0.01
NaturalLossA2=0.02
NaturalLossB2=0.02
NaturalLossA3=0.01
NaturalLossB3=0.01
NaturalLossA4=0.07
NaturalLossB4=0.07
NaturalLossA5=0.06
NaturalLossB5=0.06
NaturalLossA6=0.06
NaturalLossB6=0.06
NaturalLossA7=0.03
NaturalLossB7=0.03
NaturalLossA8=0.03
NaturalLossB8=0.03
NaturalLossA9=0.16
NaturalLossB9=0.16
NaturalLossA10=0.16
NaturalLossB10=0.16
NaturalLossA11=0.17
NaturalLossB11=0.17
NaturalLossA12=0.01
NaturalLossB12=0.01

[assiml]
respdarkParam=1.2

[bioch]
d0=1
a1=6.6

[Biomass respiration]
Value=0.002

[Specific leaf area]
Value=0.04

[Beam extinction coefficent]
Value=0.35

[Diffuse extinction coefficent]
Value=0.5

[Maximum potential electron transport rate]
Value=85

[Temperature for photosynthesis]
Min=-15
Opt=15
```

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```
Max=40

[Carbon assimilate partitioning coefficent]
Leaf=0.8
Branch=0.001
Stem=0.001
Root=0.2

[Fraction of litter entering DPM]
Leaf=0.6
Branch=0.001
Stem=0.001
Root=0.6
```

A.3. Appendix IIb Example plant parameter file for type "managed grass"

```
[Description]
Name=Managed Grass Example

[Main]
MainAirTempThreshhold=-15
rmParam1=0.1
rmParam2=0.01
rmParam3=0.1
NPPFactor=0.8

[Management]
Type=Managed
Additions=Grass

PlantingDay=0

EventDay1=174
EventLossA1=0.9
EventLossB1=0.01
EventLossR1=0.7

EventDay2=194
EventLossA2=0.7
EventLossB2=0.01
EventLossR2=0.1

EventDay3=204
EventLossA3=0.7
EventLossB3=0.01
EventLossR3=0.1

NaturalLossA1=0.01
NaturalLossB1=0.01
NaturalLossA2=0.02
NaturalLossB2=0.02
NaturalLossA3=0.01
NaturalLossB3=0.01
NaturalLossA4=0.07
NaturalLossB4=0.07
NaturalLossA5=0.06
NaturalLossB5=0.06
NaturalLossA6=0.06
NaturalLossB6=0.06
NaturalLossA7=0.03
NaturalLossB7=0.03
NaturalLossA8=0.03
NaturalLossB8=0.03
NaturalLossA9=0.16
NaturalLossB9=0.16
NaturalLossA10=0.16
NaturalLossB10=0.16
NaturalLossA11=0.17
NaturalLossB11=0.17
NaturalLossA12=0.01
NaturalLossB12=0.01

[assiml]
respdarkParam=1.2

[bioch]
d0=1
a1=6.6

[Biomass respiration]
```

```
Value=0.002

[Specific leaf area]
Value=0.04

[Beam extinction coefficent]
Value=0.35

[Diffuse extinction coefficent]
Value=0.5

[Maximum potential electron transport rate]
;Value=160
Value=85

[Temperature for photosynthesis]
Min=-15
Opt=15
Max=40

[Carbon assimilate partitioning coefficent]
Leaf=0.8
Branch=0.001
Stem=0.001
Root=0.2

[Fraction of litter entering DPM]
Leaf=0.6
Branch=0.001
Stem=0.001
Root=0.6
```

A.4. Appendix IIc Example plant parameter file for type "crops"

```
[Description]
Name=Crop Example

[Main]
MainAirTempThreshhold=-15
rmParam1=0.1
rmParam2=0.01
rmParam3=0.1
NPPFactor=0.8

[Management]
Type=Managed
Additions=Crops

PlantingDay=90
HarvestingDay=250
HarvestLossA=0.15
HarvestLossB=0.05
HarvestLossR=0.8

NaturalLossA1=0.01
NaturalLossB1=0.01
NaturalLossA2=0.02
NaturalLossB2=0.02
NaturalLossA3=0.01
NaturalLossB3=0.01
NaturalLossA4=0.07
NaturalLossB4=0.07
NaturalLossA5=0.06
NaturalLossB5=0.06
NaturalLossA6=0.06
NaturalLossB6=0.06
NaturalLossA7=0.03
NaturalLossB7=0.03
NaturalLossA8=0.03
NaturalLossB8=0.03
NaturalLossA9=0.16
NaturalLossB9=0.16
NaturalLossA10=0.16
NaturalLossB10=0.16
NaturalLossA11=0.17
NaturalLossB11=0.17
NaturalLossA12=0.01
NaturalLossB12=0.01

[assiml]
respdarkParam=1.2

[bioch]
d0=1
a1=6.6

[Biomass respiration]
Value=0.002

[Specific leaf area]
Value=0.04

[Beam extinction coefficent]
Value=0.35

[Diffuse extinction coefficent]
Value=0.5
```

4-16

```
[Maximum potential electron transport rate]
;Value=160
Value=85

[Temperature for photosynthesis]
Min=-15
Opt=15
Max=40

[Carbon assimilate partitioning coefficent]
Leaf=0.8
Branch=0.001
Stem=0.001
Root=0.2

[Fraction of litter entering DPM]
Leaf=0.6
Branch=0.001
Stem=0.001
Root=0.6
```