CornSoy Simulation(CSS) API Documentation

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Contents

1. Introduction

This document details the various Application Programming Interfaces (APIs) offered by Corn-SoyWater application.

2. Background

ConSoyWater is an application developed to assist farmers with irrigation decisions for their corn and soybean crops. Originally designed for the high plains region (Nebraska and surrounding states), the application relies on the core corn and soybean simulation models (https://hybridmaize.unl.edu/ [1]) and (https://soysim.unl.edu/ [2]) developed at Department of Agronomy & Horticulture, University of Nebraska-Lincoln.

Growth and productivity of any crop depends on a variety of factors that it experiences during its lifetime. CornSoywater simulates the development and growth of crops based on four main categories of inputs:

- *Weather conditions* – amount of sunlight, temperature, wind speed and precipitation experienced by the field.
- *Soil conditions* – texture, density, residue and moisture of the soil in the field.
- *Water content* – amount of rainfall and irrigation done at various crop stages.
- *Others* - plant population, relative maturity etc

Precisely, it generates recommendations for the following:

- *Day to day simulation*: simulation of crop-stage and growth from the planting date to 10 days in advance.
- *Available water*: available water within active rooting zone, available water of the first, second and third foot of soil, available soil water at a 50% depletion
- *Water stress:* a number in range 0 to 1 that predicts whether the crop is already under water-stress, or will be subjected to water-stress in near future.
- *Other aggregate information:* initial water available to active rooting depth, total rainfall amount since planting, total water consumption, total irrigation amount and water losses by drainage and canopy interception.

3. Corn-Soy Simulation (CSS) API Overview

Cornsoy Simulation (CSS) API is a PHP based API that runs over a POST endpoint on hprcc-agron0.unl.edu. Requests/Responses are JSON-formatted objects. A basic level of authentication is provided using an API Key which is uniquely generated by the CornSoywater team for each valid user.

4. API Types

4.1 Weather Station API Request:

This API can be used to get

- Details of the closest weather station given a field latitude and longitude.
- Details of weather station given its unique identification number (awdnId).
- List/Details of weather stations located in a state.
- List/Details of weather stations whose name closely match all or part of given name.

API EndPoint:

```
http://hprcc-agron0.unl.edu/cornsoywater/api/weather
```

Input parameters and descriptions:

Parameter Name	Description
apikey	Unique APIKey provided to the user
fieldLat	Field latitude between -180 to 180 degrees
fieldLon	Field longitude between -180 to 180 degrees
stnState	Station State
stnId	AWDNId
stnName	Name or part of Station name

Table 1 - Input request parameters for Weather Station API

Ouput parameters and descriptions:

Parameter Name	Description
field_latitude	Field latitude if provided as part of input parameter in the request
field_longitude	Field latitude if provided as part of input parameter in the request
stnState	Station State if provided as part of input request
stnId	AWDNId if provided as part of input request
stnName	as provided as part of input request
count	Total number of records present in the output
records	Array of records of weather stations generated as part of the results

Each record in the result contains the following attributes:

idAWDN	AWDN id of the weather station
stnName	Name of the weather station
stnLat	Weather Station latitude
stnLong	Weather Station longitude
stnStartDate	Date station was first active/created or started sending data
stnEndDate	Date station was last active or stopped sending data
stnElev	Weather Station Elevation
stnStatus	Status – active or disabled
stnState	State of the weather station
stnDataSource	Data Source – AWDN or nonAWDN
stnMiles	Distance in miles from the field (only of fieldLat/fieldLon is provided as part of input request)

Table 2 – Output response attributes for Weather Station API

4.2 Weather Station API Examples:

4.2.1 Example 1 – nearest weather station(s)

Find the nearest weather station(s) to a corn field is located in De Moines, IA at (41.59, -93.60).

The input JSON request should look like the following:

```
{
    "apikey":"e57c858f031526a86bcd7caf50842cf2",
    "fieldLat":"41.59",
    "fieldLon":"-93.60"
}
```

Once this request is submitted to the API endpoint (http://hprcc-agron0.unl.edu/cornsoywater/api/weather) over POST,

The JSON response provided by the API will be similar to the following:

```
{
  "field_latitude":"41.59",
  "field_longitude":"-93.60",
 " count":2,
 "records":[
        {
            "idAWDN":"a130200",
```

```
          "stnName":"AMES AEA AGFARM",
          "stnLat":"42.02",
          "stnLong":"-93.77",
          "stnStartDate":"2013-12-31",
          "stnEndDate":"2019-04-01",
          "stnElev":"335.00",
          "stnStatus":"1",
          "stnState":"IA",
          "stnDataSource":"AWDN",
          "stnMiles":30.971896377459
       },
       {
          "idAWDN":"a130209",
          "stnName":"AMES AGRONOMY",
          "stnLat":"42.02",
          "stnLong":"-93.77",
          "stnStartDate":"1986-07-01",
          "stnEndDate":"2017-05-15",
          "stnElev":"309.00",
          "stnStatus":"0",
          "stnState":"IA",
          "stnDataSource":"AWDN",
          "stnMiles":30.971896377459
       }
     ]
  }
```

4.2.2   Example 2 – weather station(s) matching given name

Find the weather station(s) with name like "ames".

JSON API request

```
{"apikey":"e57c858f031526a86bcd7caf50842cf2","stnName":"ames"}
```

Once this request is submitted to the API endpoint (http://hprcc-agron0.unl.edu/cornsoywater/api/weather) over POST, the response received will be as follows:

JSON Response

```
{
"station_name":"ames",
"count":4,
records:[
{
    "idAWDN": "a130200",
    "stnName": "AMES AEA AGFARM",
    "stnLat": "42.02",
    "stnLong": "-93.77",
    "stnStartDate": "2013-12-31",
    "stnEndDate": "2019-04-01",
    "stnElev": "335.00",
    "stnStatus": "1",
    "stnState": "IA",
    "stnDataSource": "AWDN"
}
……….
………
……. (4 records)
}]
}
```

4.2.3   Example 3 – weather station(s) located in a given state

Find all weather station(s) located in Nebraska (NE).

JSON API request

```
{"apikey":"e57c858f031526a86bcd7caf50842cf2","stnState":"ne"}
```

Once this request is submitted to the API endpoint (http://hprcc-agron0.unl.edu/cornsoywater/api/weather) over POST, the response received will be as follows:

JSON Response

```
{
"station_state":"ne",
"count":91
records:[
{
    "idAWDN": "a250059",
```

```
    "stnName": "AINSWORTH 2NE",
    "stnLat": "42.57",
    "stnLong": "-99.83",
    "stnStartDate": "1984-06-03",
    "stnEndDate": "2019-04-01",
    "stnElev": "765.00",
    "stnStatus": "1",
    "stnState": "NE",
    "stnDataSource": "AWDN"
}
…………
…….
…... (91 records)
}]
}
```

4.3 Corn API Request

This API can be used to get the simulation data from the Hybrid-Maize model [1]. It provides the following types of simulation data:

- *Day to day simulation*: simulation of crop-stage and growth from the planting date to 10 days in advance.
- *Available water*: available water within active rooting zone, available water of the first, second and third foot of soil, available soil water at a 50% depletion
- *Water stress:* a number in range 0 to 1 that predicts whether the crop is already under water-stress, or will be subjected to water-stress in near future.
- *Other aggregate information:* initial water available to active rooting depth, total rainfall amount since planting, total water consumption, total irrigation amount and water losses by drainage and canopy interception.

API EndPoint:

```
http://hprcc-agron0.unl.edu/cornsoywater/api/corn
```

Input parameters and descriptions:

Parameter Name	Mandatory /Optional	Description
apikey	M	Unique APIKey provided to the user
flat	M	Field latitude between -180 to 180 degrees
flon	M	Field longitude between -180 to 180 degrees
cpdate	M	Crop planting date in mm/dd/yyyy format
crmaturity	O	Crop relative maturity in days (default : 90)

cppopulation	O	Plant population in x1000/acre (default: 20)
srdepth	O	Soil rooting depth in inches (default: 35)
ssresidues	O	Surface residues coverage in percentage (default:75)
tsdensity	O	Top soil bulk density - between 1.2 to 1.5 (default: 1.2)
tsmoisture	O	Top soil (1 foot) moisture at planting in percentage, see Table (default: 75)
ssmoisture	O	Top soil (1 foot) moisture at planting in percentage, see Table (default: 75)
tstexture	O	Top soil (1 foot) texture, see Table (default:3)
sstexture	O	Sub soil (below 1 foot) texture, see Table (default:3)
sresult	M	Type of simulation needed as response, see Table (default: aggr)

sresult can be one of the four values described below. Based on the value, the appropriate JSON response is generated and sent to the sender.

Value	Description
cstage	Day-by day simulation of crop-stage and growth (phenology) from the planting date to 10 days in advance
awater	Day-to-day simulation records of rain, irrigation, threshold, total available water, available water of the first, second and third foot of soil from the planting date to 10 days in advance
wstress	Day-to-day prediction records for water stress (0 or 1) from planting date to 10 days in advance
aggr	Aggregate results for available water, total rainfall amount, total irrigation amount, water drain, water consumption and current water balance.

Table 3 – Input JSON request parameters for Corn API

Output parameters and descriptions:

General:

Attribute Name	Description
field_latitude	Field latitude provided in input JSON request
field_longitude	Field longitude provided in input JSON request
planting_date	Crop planting date provided in input JSON request
count	Total number of records present in the simulation output
records	Array of output records based on the requested query

Crop stage records

Attribute Name	Description
date	date from planting date to 10 days in future in (mm/dd) format
phenology	phenology type corresponding to the date (for corn phenology types, refer to Table 8 in Appendix section)

Available water records

Attribute Name	Description
date	date from planting date to 10 days in future in (mm/dd) format
rain	rainfall amount in inches on the date
irrigation	Irrigation amount in inches on the date
water_1ft	Available water in inches of the first foot of the soil on the date
water_2ft	Available water in inches of the second foot of the soil on the date
water_blw2ft	Available water in inches below the second foot of the soil on the date
threshold	Water depletion threshold on the date which is set to: • 50% for most stages of the crop • 40% for silking/pollination stages • 60% for last week before maturity of the crop
total_available_water	Total available water within active rooting zone on the date

Water stress records

Parameter Name	Description
date	date from planting date to 10 days in future in (mm/dd) format
wstress	a number between 0(indicates stomata are fully open indicating no stress) to 1(indicates stomata are fully closed) on the corresponding date

Aggregate records

Parameter Name	Description
available_water	Initial available water down to active rooting depth at planting
total_rainfall	Total rainfall amount since planting
total_irrigation	Total irrigation amount
water_drain	Water losses, including canopy interception and drain below user-chosen maximum rooting depth
water_consumption	Water consumption (i.e., total crop ET) since planting
current_water_balance	Current available water balance within the active rooting zone

Table 4 – Output JSON response attributes for Corn API

4.4 Corn API Examples:

4.4.1 Example 1 – corn crop stages and growth

John's corn field is located at intersection of 130th street/660th Avenue, McCallsburg, IA. The latitude/longitude of the field is approximately (42.1609,-93.3752). The planting date of the field was 03/18/2019 with relative maturity 90. The planted population was 28000 per acre and soil rooting depth was 60 inches. The surface residues coverage was about 50% and the bulk density of top soil was measured to be 1.3. The soil conditions (both top and sub soil) were wet (75% moisture) at the time of planting. The soil textures (both top and sub soil) of his field are Loam. He irrigated the crop twice after planting, once on 03/25/2019 with 1.1 inches and on 04/03/2019 with 0.8 inches. The current date is 4/23/2019

John's Corn field location in McCallsburg, IA

John wants to use the CornSoyAPI to know the simulated crop-stages and growth for this crop field on all days from the planting date to 10 days in advance. The json api request would look like the following:

JSON API request

```
{
 "apikey":"e57c858f031526a86bcd7caf50842cf2",
 "flat":"40.505664",
 "flon":"-98.966389",
 "cpdate":"03/18/2019",
 "crmaturity":"90",
 "cppopulation":"28",
 "srdepth":"60",
 "ssresidues":"50",
 "tsdensity":"1.3",
 "tsmoisture":"75",
 "ssmoisture":"75",
 "tstexture":"4",
 "sstexture":"4",
 "sresult":"cstage",
 "irrdata":[    {"date":"03/25/2019","amount":"1.1"},
               {"date":"04/03/2019","amount":"0.8"}
            ]
}
```

Notice, that the soil texture parameters (tstexture/sstexture) have been populated using Table 8 – soil texture values (Loam → 4)

Once this request is submitted to the API endpoint (http://hprcc-agron0.unl.edu/cornsoywater/api/corn) over POST, he would get a response as follows:

JSON API Response

```
records:
{
    "field_latitude": "42.160938",
    "field_longitude": "-93.375270",
    "planting_date": "3/18/2019",
    "count": 46,
    "records": [
        {
            "date": "3/18",
            "phenology": "NE"
        },
        {
            "date": "3/19",
            "phenology": "NE"
        },
        {
            "date": "3/20",
            "phenology": "NE"
        },
        {
```

```
                "date": "3/21",
                "phenology": "NE"
        },
        {
                "date": "3/22",
                "phenology": "NE"
        },
        {
                "date": "3/23",
                "phenology": "NE"
        },
…………
…….
…………
        {
                "date": "4/18",
                "phenology": "V1"
        },
…………
…….
{
                "date": "5/1",
                "phenology": "V1"
        },
        {
                "date": "5/2",
                "phenology": "V1"
        }
…(46 records in total)
    ]
}
```

4.4.2   Example 2 – corn water stress

Suppose, John wants know the predicted water stress using the API on various days for the same field (above in example 1) from the planting date to 10 days in advance. The json api request would look like the following:

JSON API request

```
{
 "apikey":"e57c858f031526a86bcd7caf50842cf2",
 "flat":"40.505664",
 "flon":"-98.966389",
```

```
  "cpdate":"03/18/2019",
  "crmaturity":"90",
  "cppopulation":"28",
  "srdepth":"60",
  "ssresidues":"50",
  "tsdensity":"1.3",
  "tsmoisture":"75",
  "ssmoisture":"75",
  "tstexture":"4",
  "sstexture":"4",
  "sresult":"wstress",
  "irrdata":[   {"date":"03/25/2019","amount":"1.1"},
               {"date":"04/03/2019","amount":"0.8"}
            ]
}
```

Notice, that the soil texture parameters (tstexture/sstexture) have been populated using Table 8 – soil texture values (Loam → 4)

And the response generated would be:

JSON API response

```
records:
{
    "field_latitude": "42.160938",
    "field_longitude": "-93.375270",
    "planting_date": "3/18/2019",
    "count": 46,
    "records": [
        {
            "date": "3/18",
            "wstress": "0.00"
        },
        {
            "date": "3/19",
            "wstress": "0.00"
        },
…………
…….
…….
        {
            "date": "4/30",
            "wstress": "0.00"
        },
        {
            "date": "5/1",
            "wstress": "0.00"
        },
```

```
        {
            "date": "5/2",
            "wstress": "0.00"
        }
…(46 records in total)
    ]
}
```

4.4.3   Example 3 – available water for corn

Similarly, if John wants know the available water information using the API on all the days for the same field (above in example 1) from the planting date to 10 days in advance. The json api request would look like the following:

JSON API request

```
{
 "apikey":"e57c858f031526a86bcd7caf50842cf2",
 "flat":"40.505664",
 "flon":"-98.966389",
 "cpdate":"03/18/2019",
 "crmaturity":"90",
 "cppopulation":"28",
 "srdepth":"60",
 "ssresidues":"50",
 "tsdensity":"1.3",
 "tsmoisture":"75",
 "ssmoisture":"75",
 "tstexture":"4",
 "sstexture":"4",
 "sresult":"awater",
 "irrdata":[   {"date":"03/25/2019","amount":"1.1"},
               {"date":"04/03/2019","amount":"0.8"}
             ]
}
```

And the response from the server would look like:

JSON API response

```
records:
{
    "field_latitude": "42.160938",
    "field_longitude": "-93.375270",
    "planting_date": "3/18/2019",
```

```
    "count": 46,
    "records": [
        {
            "date": "3/18",
            "rain": "0.00",
            "irrigation": "0.00",
            "water_1ft": "1.68",
            "water_2ft": "0.00",
            "water_blw2ft": "0.00",
            "threshold": "1.12",
            "total_available_water": "1.68"
        },
        {
            "date": "3/19",
            "rain": "0.00",
            "irrigation": "0.00",
            "water_1ft": "1.64",
            "water_2ft": "0.00",
            "water_blw2ft": "0.00",
            "threshold": "1.12",
            "total_available_water": "1.64"
        },
…………
…….
…….
        {
            "date": "5/1",
            "rain": "0.02",
            "irrigation": "0.00",
            "water_1ft": "1.42",
            "water_2ft": "0.00",
            "water_blw2ft": "0.00",
            "threshold": "1.12",
            "total_available_water": "1.42"
        },
        {
            "date": "5/2",
            "rain": "0.00",
            "irrigation": "0.00",
            "water_1ft": "1.38",
            "water_2ft": "0.00",
            "water_blw2ft": "0.00",
            "threshold": "1.12",
            "total_available_water": "1.38"
        }
```

```
…(46 records in total)
    ]
}
```

4.4.4   Example 4 – aggregate information

Similarly, if John wants know the aggregate/summary water information using the API for the same field (above in example 1). The json api request would look like the following:

JSON API request

```
{
 "apikey":"e57c858f031526a86bcd7caf50842cf2",
 "flat":"40.505664",
 "flon":"-98.966389",
 "cpdate":"03/18/2019",
 "crmaturity":"90",
 "cppopulation":"28",
 "srdepth":"60",
 "ssresidues":"50",
 "tsdensity":"1.3",
 "tsmoisture":"75",
 "ssmoisture":"75",
 "tstexture":"4",
 "sstexture":"4",
 "sresult":"aggr",
 "irrdata":[    {"date":"03/25/2019","amount":"1.1"},
               {"date":"04/03/2019","amount":"0.8"}
            ]
}
```

And the response from the server would look like:

JSON API response

```
results:
{
    "available_water": "1.7",
    "total_rainfall": "0.6",
    "total_irrigation": "0.0",
    "water_drain": "0.0",
    "water_consumption": "0.9",
    "current_water_balance": "1.4"
}
```

4.5 Soybean API Request:

This API can be used to get the simulation data from the SoySim model [2]. It provides the following types of simulation data:

- *Day to day simulation*: simulation of crop-stage and growth from the planting date to 10 days in advance.
- *Available water*: available water within active rooting zone, available water of the first, second and third foot of soil, available soil water at a 50% depletion
- *Water stress:* a number in range 0 to 1 that predicts whether the crop is already under water-stress, or will be subjected to water-stress in near future.
- *Other aggregate information:* initial water available to active rooting depth, total rainfall amount since planting, total water consumption, total irrigation amount and water losses by drainage and canopy interception.

API EndPoint:

```
http://hprcc-agron0.unl.edu/cornsoywater/api/soy
```

Input parameters and descriptions:

Parameter Name	Mandatory /Optional	Description
apikey	M	Unique APIKey provided to the user
flat	M	Field latitude between -180 to 180 degrees
flon	M	Field longitude between -180 to 180 degrees
cpdate	M	Crop planting date in dd/mm/yyyy format
cmgroup	O	Crop maturity group (normally between 1.0 to 4.5, default 3.0
sresult	M	Name or part of Station name
srdepth	O	Soil rooting depth in inches (generally between 20 to 50, default 35)
sawater	O	Available water percentage on planting date (between 0 to 100, default 75)
satexture	O	Soil Texture to rooting depth, see Table <> below
ssdepth	O	Seed Depth (generally between 1.0 to 4.5, default 1.18)
swdepletion	O	Soil water depletion threshold percentage(between 0 to 100, default 65)
irrdata	O	Array of irrigation data containing date and amount of irrigation (in inches) – see Table <> below
sresult	M	Simulation result needed - one of four options, see detailed description below

> *sresult* can be one of the four values described below. Based on the value, the appropriate response is generated and sent to the sender.

Value	Description
cstage	Day-by day simulation of crop-stage and growth (r_phenology, v_phenology) from the planting date to 10 days in advance
awater	Day-to-day simulation records of rain, irrigation, threshold and water deficit from the planting date to 10 days in advance
wstress	Day-to-day prediction records for water stress (0 or 1) from planting date to 10 days in advance
aggr	Aggregate results for initial water available to active rooting depth, total rainfall amount since planting, total water deficit, total irrigation amount and current available water.

Table 5 – Input JSON request parameters for Soybean API

Output parameters and descriptions:

General:

Parameter Name	Description
field_latitude	Field latitude provided in input JSON request
field_longitude	Field longitude provided in input JSON request
planting_date	Crop planting date provided in input JSON request
count	Total number of records present in the simulation output
records	Array of output records based on the requested query

Crop stage records

Parameter Name	Description
date	date from planting date to 10 days in future in (mm/dd) format
r_phenology	Reproductive stage phenology type, (see Table 9 in Appendix section)
v_phenology	Vegetative stage phenology type, (see Table 9 in Appendix section)

Available water records

Parameter Name	Description
date	date from planting date to 10 days in future in (mm/dd) format
threshold	Available soil water at 50% depletion threshold
rain	Rainfall amount in inches on the corresponding date
irrigation	Irrigation amount in inches on the corresponding date
water_deficit	

Water stress records

Parameter Name	Description
date	date from planting date to 10 days in future in (mm/dd) format
wstress	A number between 0 and 1 indicating water stress

Aggregate records

Parameter Name	Description
initial_available_water	Initial available water in 0 - 12 inch soil zone at planting
total_rain	Total rainfall amount since planting
total_irrigation	Total irrigation amount
total_water_deficit	Water consumption (i.e., total crop ET) since planting
current_available_water	Current available water balance within the active rooting zone

Table 6 – Output JSON response attributes for Soybean API

4.6 Soybean API Examples:

4.4.1   Example 1 – soybean crop stages and growth
To be Added

JSON API request

Once this request is submitted to the API endpoint (http://hprcc-agron0.unl.edu/cornsoywater/api/soy) over POST, he would get a response as follows:

JSON API Response

```

```

4.4.2 Example 2 – corn water stress
To be Added

JSON API request

```

```

And the response generated would be:

JSON API response

```

```

4.4.3 Example 3 – available water for corn
To be Added

JSON API request

```

```

And the response from the server would look like:

JSON API response

```

```

4.4.4 Example 4 – aggregate information
To be Added

JSON API request

```

```

And the response from the server would look like:

JSON API response

4. Appendix

Following are a list of tables referred to in the API's above:

Table 6 – Amount of moisture in the soil

Value (in percentage)	Description
100	100% available water (`Very Wet`)
75	75% available water (`Wet`)
50	50% available water (`Moist`)
25	25% available water (`Dry`)

Table 7 - Soil Texture Values

Used for both top-soil and subsoil (below 1 foot)

Value	Description
1	Loamy Sand
2	Sandy loam
3	Silt loam
4	Loam
5	Sandy clay loam
6	Silty clay loam
7	Clay loam
8	Clay
9	Silty clay

Table 8 – Corn Phenology Types and Description

Value	Description
NE	Emergence stage
V1 – V15	Stand Establishment, rapid growth, dry matter stages
R1, Silking	Last state of pollination

R2, Blister	The blister stage is approximately 10 to 14 days after silking at 1660 GDUs.2 During this stage the kernel is white and shaped like a blister
R3, Milk	Milk stage (18 to 22 days after silking), the kernel is yellow with a white milky inner liquid. At this stage dry matter accumulation is very rapid. Silks on the corn ear are brown and dry.
R4, Dough	During the dough stage (24 to 28 days after silking/1925 GDUs) the inner fluid begins to thicken due to starch accumulation. The kernels will have accumulated half of their total dry weight.
R5, Dent	At dent stage (35 to 42 days after silking/2190 to 2450 GDUs) the kernels begin to dry down from the top of the kernel towards the cob. Each kernel will have a dent at the top. If a frost occurs during this stage, the black layer can form prematurely preventing additional dry matter accumulation.
R6, Blacklayer	The kernels continue to gain weight until black layer formation or physiological maturity (55 to 65 days after silking/approximately 2700 GDUs) occurs. The black layer forms where the kernel attaches to the cob. Kernel moisture is at 30 to 35 percent.

Table 9 – Soybean Phenology Types and Description

Value	Description
VE	Emergence, Cotyledons above the soil surface
V1 - Vn	Set of states for developed leaves and number of nodes above the stem
R1	Beginning bloom, One open flower at any node on the main stem
R2	Full bloom, Open flower at one of the two uppermost nodes on the main stem with a fully develped leaf
R3	Beginning pod, Pod 5 mm (3/16 inch) long at one of the four uppermost nodes on the main stem with a fully developed leaf
R4	Full pod, Pod 2 cm (3/4 inch) long at one of the four uppermost nodes on the main stem with a fully developed leaf
R5	Beginning seed, Seed 3mm (1/8 inch) long in a pod at one of the four uppermost nodes on the main stem with a fully developed leaf
R6	Full seed, Pod containing green seed that fills the pod cavity at one of the four uppermost nodes on the main stem with a fully developed leaf
R7	Beginning maturity, One normal pod on the main stem that has reached its mature pod color
R8	Full maturity, Ninety-five percent of the pods that have reached their mature pod color

Please refer to [3] for a detailed description of soybean phenology types.

5. References

1. Hybrid-Maize Model: Yang, H. S., Dobermann, A., Lindquist, J. L., Walters, D. T., Arkebauer, T. J., & Cassman, K. G. (2004). Hybrid-maize—a maize simulation model that combines two crop modeling approaches. *Field Crops Research*, *87*(2-3), 131-154.
2. SoySim Model: Setiyono, T. D., Cassman, K. G., Specht, J. E., Weiss, A., Dobermann, A., & Yang, H. (2009). SoySim.
3. SoySim Phenology Descriptions: Retrieved from https://soysim.unl.edu/soybeanphenologydescriptions.shtml
4. PhD Thesis, James Han (2016): Retrieved from http://hprcc-agron0.unl.edu/cornsoywater/public_html/resources/Development_of_cornsoywater-A_web-based_irrigation_application_for_corn_soyabean.pdf

6. Version Information

Update Date	Version	Description
04/03/2019	0.1	Initial Draft
04/23/2019	0.2	Updated with Corn simulation Examples